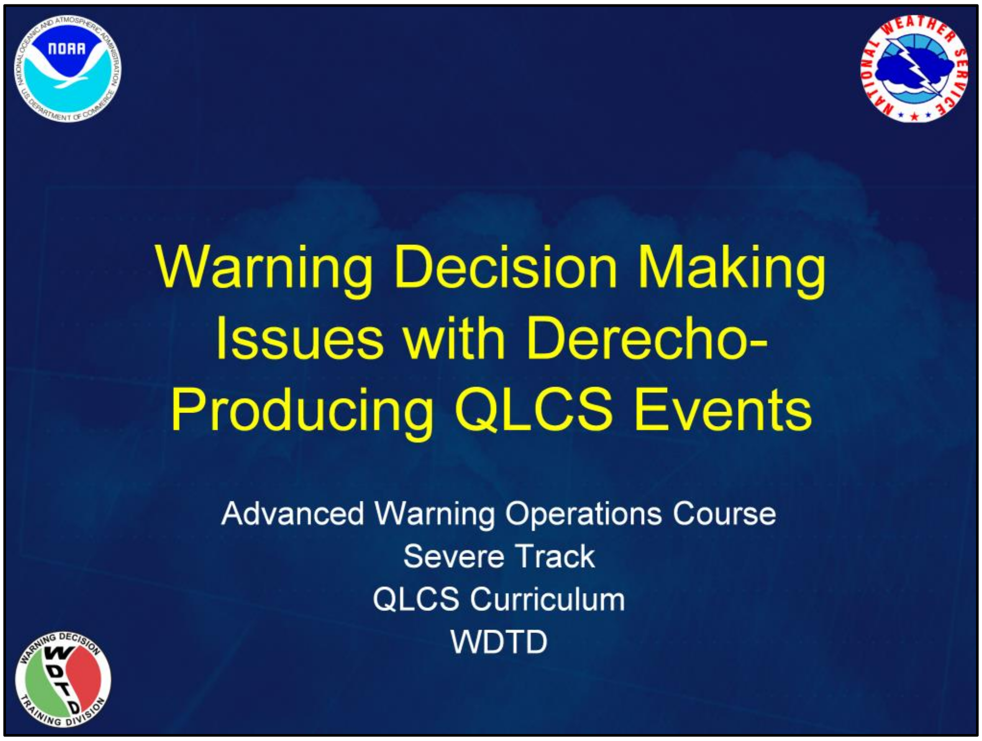

Hi, this is Brad Grant of the Warning Decision Training Branch. Welcome to a presentation Jim LaDue and myself have produced entitled, "Warning Decision Making Issues with Derecho-Producing QLCS Events". A Quasi-Linear Convective System (or QLCS) is a name for a broad class of mesoscale convective systems that have various linear configurations. A high–end QLCS event can produce a derecho if there is a sufficient amount of wind damage. This training presentation will be about 45 minutes.

Course Completion Info

Tabs - 4 Tabs (Including Introduction)

Last Modified: May 26, 2015 at 10:11 AM

PROPERTIES

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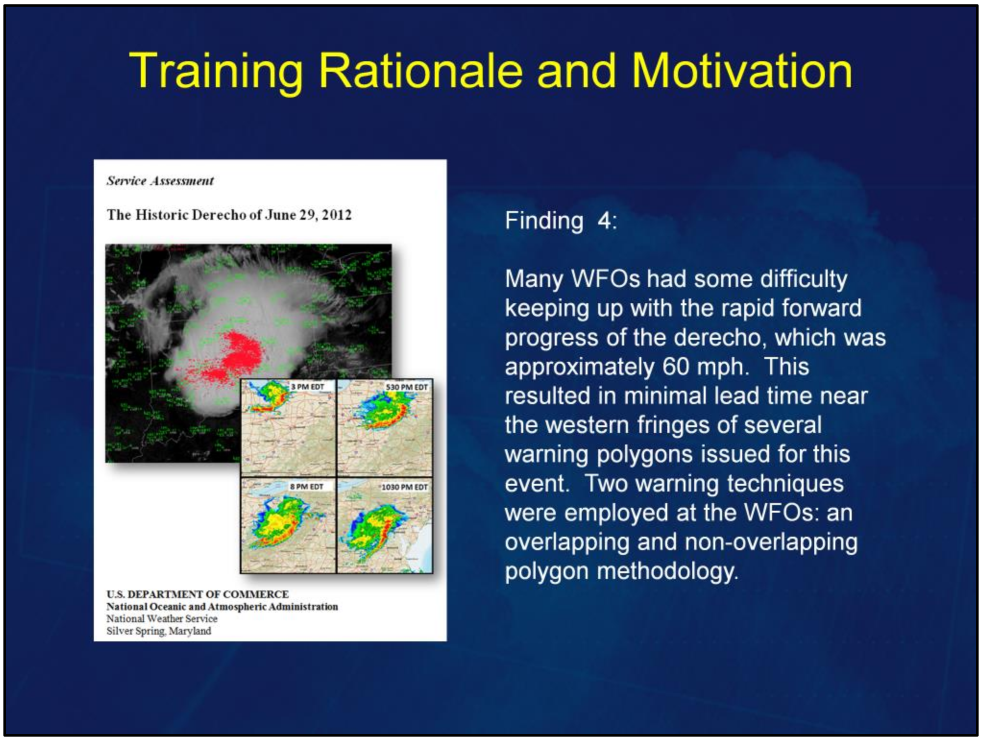
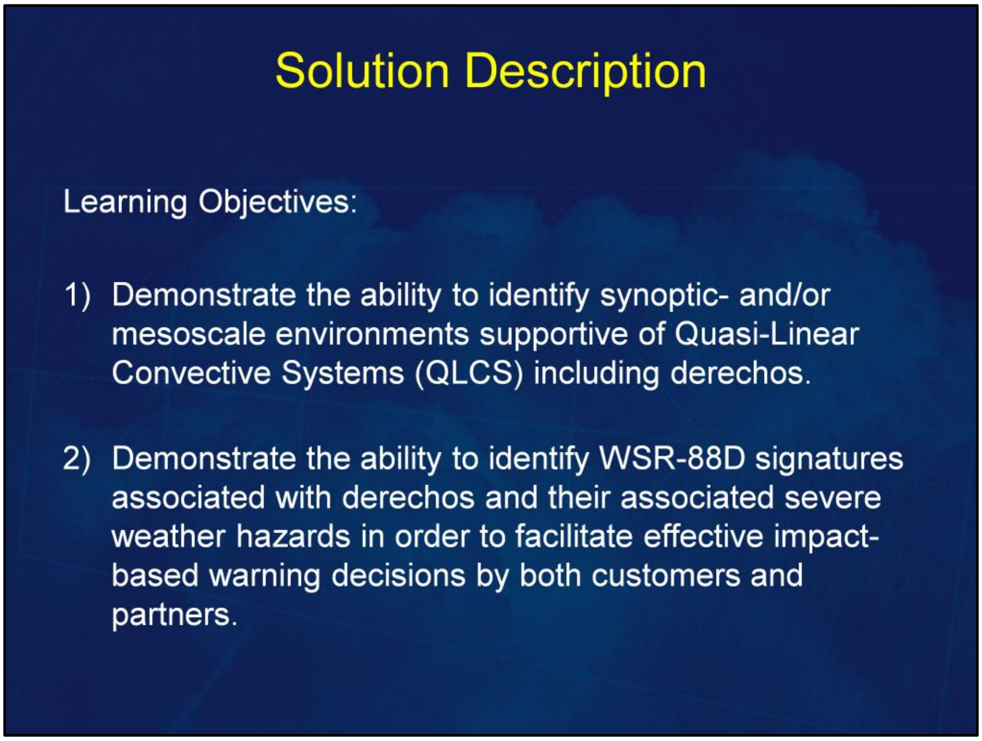
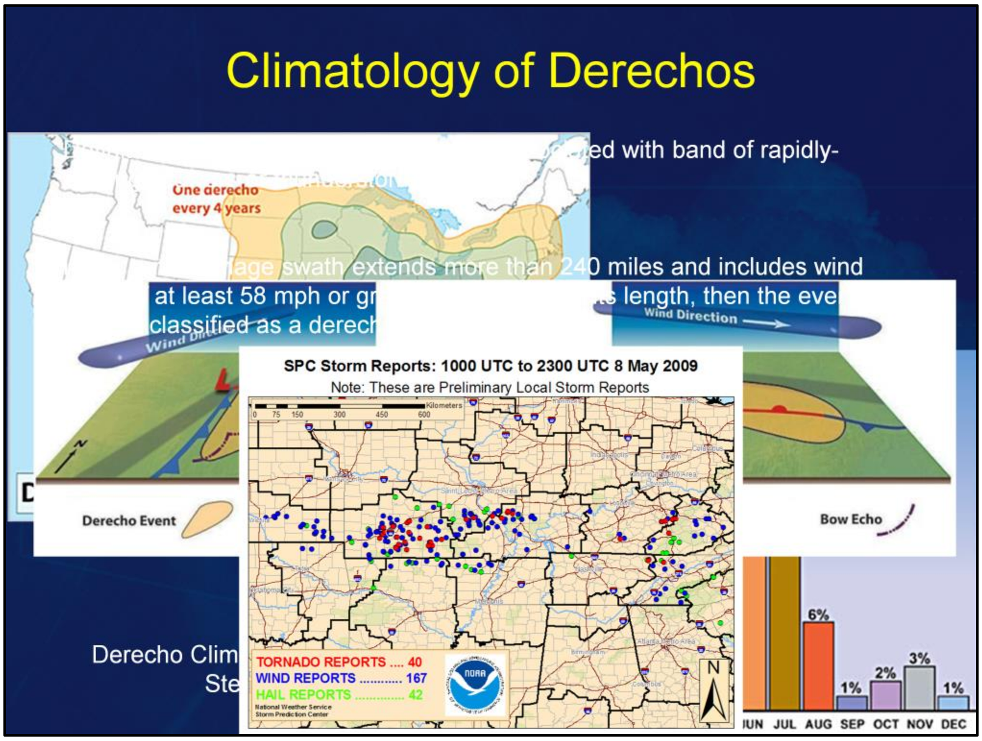


The motivation for this instruction is Finding 4 of the Historic Derecho of June 29, 2012 Service Assessment. The finding from this assessment was that in trying to keep up with warnings for this large, fast-moving QLCS, some areas did not receive adequate lead time on the western edges of their polygons. In retrospect, one of the roots of this performance problem lies with correct anticipation of the types of threats and associated impacts with QLCS events. A QLCS event such as this one was truly historic for this region but meteorological speaking, has some counterparts that can be used to illustrate important points in storm structure and phenomenology.



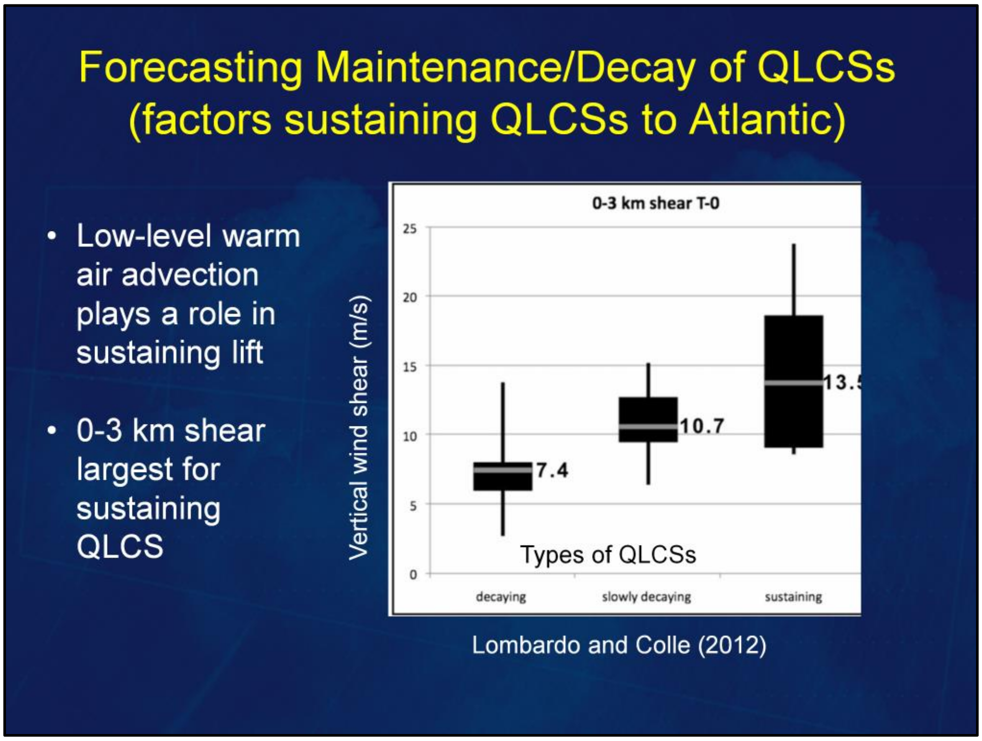
So, we have designed a learning plan called “Derecho Basics” that leverages existing WDTB training on threat assessment and storm interrogation strategies of QLCS, especially with respect diagnosing the types of structures and lifecycle identification that can provide better impact-based warning services. These are the two learning objectives in the lesson:. 1) Demonstrate the ability to identify synoptic- and/or mesoscale environments supportive of Quasi-Linear Convective Systems (QLCS) including derechos. And 2) Demonstrate the ability to identify WSR-88D signatures associated with derechos and their associated severe weather hazards in order to facilitate effective impact-based warning decisions by both customers and partners.



To start out this lesson, here's a little review of the basics of the characteristics of this type of storm system. A derecho is defined as a widespread, long-lived wind storm that is associated with a band of rapidly moving showers or thunderstorms. Although a derecho can produce destruction similar to that of tornadoes, the damage typically is directed in one direction along a relatively straight swath. As a result, the term "straight-line wind damage" sometimes is used to describe derecho damage. By definition, if the wind damage swath extends more than 240 miles (about 400 kilometers) and includes wind gusts of at least 58 mph (93 km/h) or greater along most of its length, then the event may be classified as a derecho. Here is a storm report plot of a classic multi-state derecho event from May 8, 2009.

Derechos in the United States occur primarily along two axes. Based on a climatology developed from SPC, one axis extends along the "Corn Belt" from the upper Mississippi Valley southeast into the Ohio Valley, and the other from the southern Plains northeast into the mid-Mississippi Valley. During the cool season (September through April), derechos are relatively infrequent, but are most likely to occur from east Texas into the southeastern states. Although derechos are extremely rare west of the Great Plains, isolated derechos have occurred over interior portions of the western United States, especially during spring and early summer.

There are two types of derechos, serial and progressive. The June 29, 2012 event fits more of the model for the progressive type. Progressive derechos are often associated with a relatively short line of thunderstorms (typically from 40 miles to 250 miles in length) that may at times take the shape of a single bow echo, particularly in the early stages of development. In some cases, the width of a progressive derecho and its associated bow echo system remain relatively narrow even though they may travel for hundreds of miles. In other cases, the progressive derecho and associated bow echo system begin relatively small, with a narrow path, but over time grow to exceed 250 miles in width. The line of thunderstorms of a progressive derecho often begins as a single bow echo that evolves into a short squall line, typically with more than one embedded bowing segment. Progressive derechos may travel for many hundreds of miles along a path that is relatively narrow compared to those of serial derechos. Often they are associated with an area of weak low pressure at the surface.



One of the challenges with forecasting maintenance or decay of QLCSs is the ability to identify which environmental parameters hold the key. In a study from Lombardo and Colle (2012) of 59 QLCS events that occurred in the Northeastern U.S., they grouped QLCS events into 3 classes based on radar evolution as they moved toward the Atlantic Coast: decaying, slowly decaying, or sustaining. It was found that 900 to 800 mb warm air advection maximum was collocated with QLCSs that were able to sustain themselves all the way to the Atlantic Ocean. The vertically localized low-level warm air advection maximum was thought to be important in destabilizing the atmosphere just above the shallow marine layer. Other factors contributing to deep midlevel synoptic scale ascent were not as pronounced, such as 500 mb convergent Q vectors or frontogenetical forcing. In addition, mean low-level shear (0- 3 km) was found to increase by around 10 kts for sustaining coastal linear convection over decaying events. In fact, the average 0-3 km shear was largest for QLCS events that are maintained over the Atlantic waters. This is in contrast to Coniglio et al. (2010) , who found no significant difference in the low-level vertical wind shear values between short-lived (< 5 h) and long-lived (< 8 h) MCSs over the central United States, within 200 km downstream of the composite system location.

Forecasting Maintenance/Decay of QLCSs (crossing Appalachians)

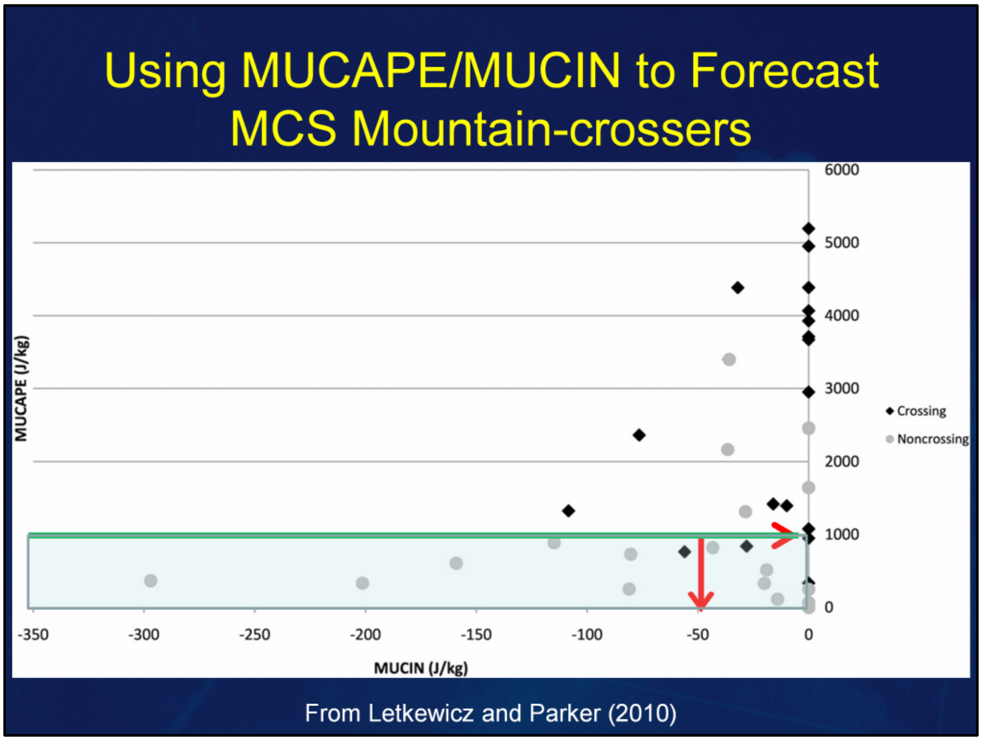
Location	Parameter	Crossing Avg	Non-Crossing Avg
Upstream	DCAPE (J/kg)	-612	-510
	0-1 km shear (m/s)	9	12
Downstream	SBCAPE (J/kg)	2371	519
	MUCAPE (J/kg)	2660	903
	Sfc-500 hPa Θ_e(K)	18	6
	0-3 km lapse rate (K/km)	7	6
	0-3 km shear (m/s)	9	16
	Sfc Θ_e(K)	345	332
	0-6 km shear (m/s)	12	20
	LCL height (m AGL)	903	522
	Mountain-perpendicular 0-3 km shear (m/s)	5	9
	MLCAPE (J/kg)	513	318
	MUCIN (J/kg)	-18	-63

From Letkewicz and Parker (2010)

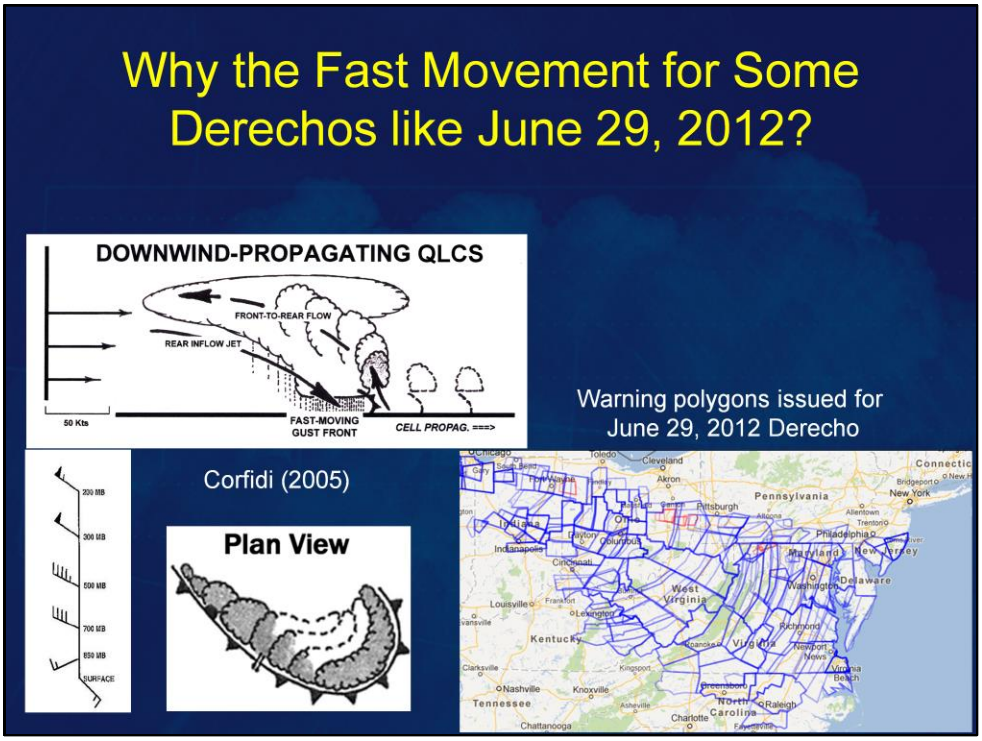
In another study by Letkewicz and Parker (2010) , they evaluated various sounding parameters for QLCSs that crossed the Appalachian Mountains. In attempt to differentiate environments that supported QLCS maintenance, they were able to stratify events into two categories which led to 20 crossing and 20 noncrossing MCS cases. The cases were largely similar in terms of their 500-hPa patterns, MCS archetypes, and orientations with respect to the barrier. Analysis of radiosonde data, however, revealed that the environment east of the mountains discriminated between case types very well. The thermodynamic and kinematic variables that had the most discriminatory power included those associated with **instability, bulk shear vector magnitudes, and mean tropospheric wind**. Crossing cases were characterized by higher instability, which was found to be partially attributable to the diurnal cycle. However, these cases also tended to occur in environments with weaker shear and a smaller mean wind.

To summarize findings from a table shown here from their study, the environment that the MCS is moving into is more important for its maintenance than the one in which it originally developed. Downdraft CAPE (DCAPE) was the parameter that best separated crossing from non-crossing MCSs west of the Appalachians. Crossing cases on average contained higher amounts of DCAPE, which can be associated with the potential for stronger (i.e., deeper) outflow, due to more evaporational cooling. This could lead to a greater chance for the MCS's cold pool to retrigger convection to the lee of the mtns. The authors warned forecasters, though, to still be somewhat wary of using DCAPE, because of the large spread of midlevel moisture values observed in the cases. SBCAPE and MUCAPE were also considerably higher in the crossing cases. The upstream kinematic parameter that best separated case types was the 0–1 km shear, which was on average, smaller for crossing cases. These results are not immediately clear.

There were also several wind speed and shear vector magnitude parameters that separated crossing and noncrossing cases well. These include 0–3 km and 0–6 km shear, and maximum bulk shear, but the relationship was not always clear, as the average of each of these parameters was smaller for crossers than noncrossers.



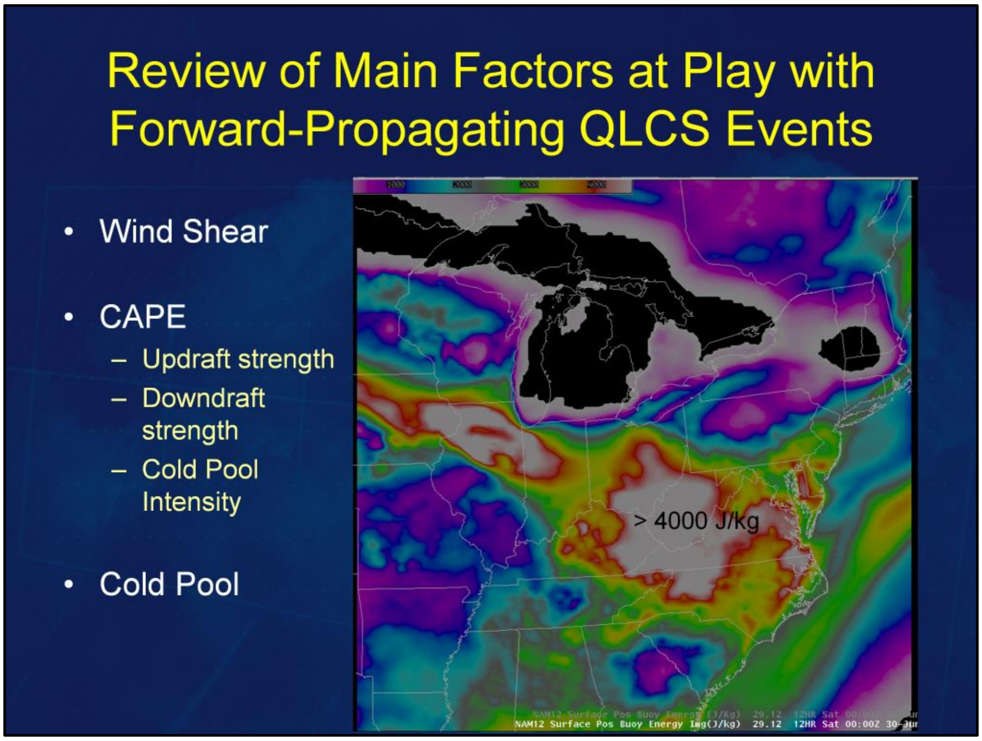
The relationship between MUCAPE and MUCIN is illustrated in this figure from Letkewicz and Parker, 2010, showing that their poor correlation is due to a wide range of MUCAPE values when MUCIN is near zero and a wide range of MUCIN values when MUCAPE is small. If a forecaster were to use a MUCAPE threshold of 1000 J/kg, then 16 of the 20 cases with values in excess of the threshold would be correctly diagnosed as crossers. Furthermore, if a forecaster were to also impose a MUCIN threshold of -50 J/kg, six of the seven cases with more than -50 J/kg of MUCIN and less than 1000 J/kg of MUCAPE would be correctly forecasted as noncrossers. Overall, they found that crossing cases tended to have thermodynamic environments in the lee of the mountains that were more favorable for convection, where MUCAPE and MUCIN are recommended as the most important operational ingredients.



So, to review, a high–end QLCS event can produce a derecho if there is a sufficient amount of wind damage. On the lower right is a Google Map of warning polygons issued for the June 29, 2012 derecho. Darker boundaries are where multiple polygons shared a common boundary. Blue polygons are severe thunderstorm warnings, red are tornado warnings. The derecho travelled at a rapid speed (50-60 mph) and thus warnings became large. So, how do some QLCSs move so rapidly? Well, it's a function of cold pool strength, mean winds, and buoyancy.

Based on Corfidi's research on propagation of multicells, as a cold pool develops and elongates, repetitive storm growth on the downwind-moving progressive part of the gust front comprises the derecho-producing convective system. It helps to perpetuate the system as long as there is sufficient buoyancy for lifting air parcels downstream. This is seen in the plan view figure. The vertical wind profile is conceptual and is based on mean winds of documented downwind producing QLCSs. The key point is that the vector magnitude and direction supports movement in the downshear direction and the movement is going to be much faster than just the mean wind.

Let's next talk a little about the factors at play in modulating a downwind-propagating, or forward propagating QLCS.



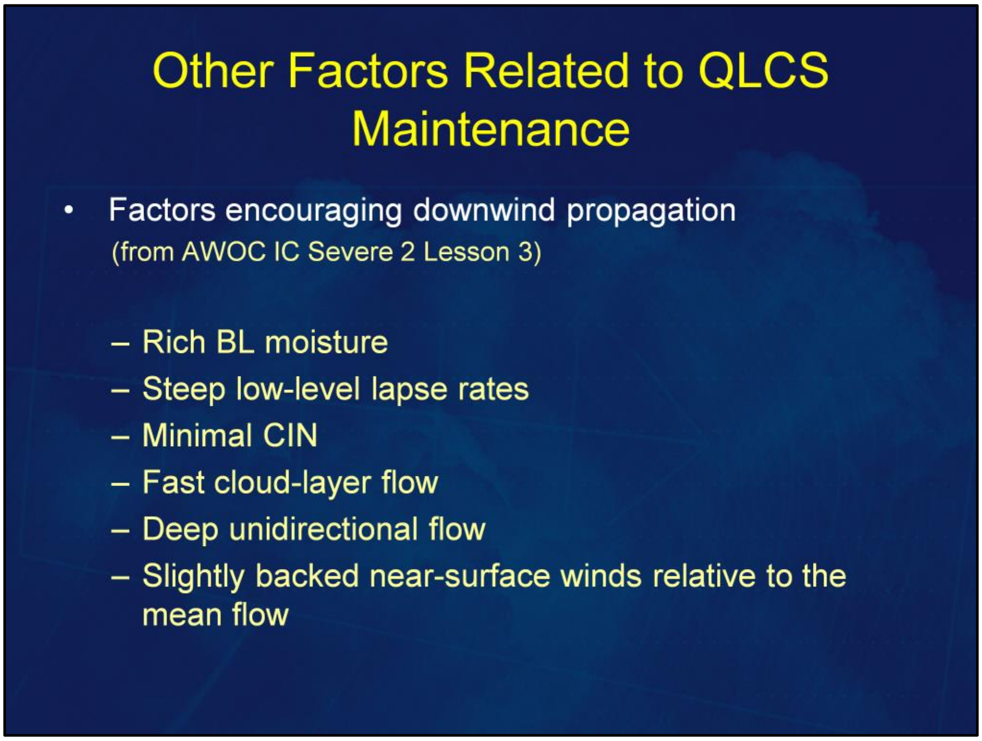
Let's take a few moments to review the main factors at play with forward propagating QLCS events.

First, deep layer shear is a discriminating ingredient in MCSs that are weak or non-severe versus those that become a derecho.

The mean hodograph from Coniglio clearly shows that shear becomes more stretched and straight-line along the x-axis (MCS-motion) as you go from the weak MCSs to the derecho MCSs (the colored numbers along the hodographs are kilometers Above Ground Level (AGL)). You can also see the huge increase in low-level storm-relative inflow for the derecho MCSs.

Buoyancy and other measures of convective instability are equally important . The role of CAPE is multifaceted. Not only is sufficient CAPE necessary to maintain intense updrafts along the leading edge of the cold pool, but the larger the CAPE the more intense the updrafts and resultant supply of moisture and energy to the overall MCS. This in turn increases the subsequent downdrafts and strengthens or at least maintains the cold pool momentum. If CAPE weakens or the outflow surges into an environment with little or no CAPE and/or significant convective inhibition, then the convective system can quickly lose its energy source and diminish quickly. Thus, vertically integrated buoyancy is often used as a convenient measure of potential cold pool intensity, but there are limitations as the computations do not account for the role of midlevel dry air.

In the case of the evening of June 29, 2012, there was ample CAPE downstream to perpetuate and intensify the system as you can see from this AWIPS D2D screen capture of the 12 hr forecast of CAPE from the NAM valid at 00z on the evening of June 29. Values above 3000 J/kg are every image contour inside the yellow color in the image and values > 4000 are annotated. These values actually stayed pretty high throughout the evening.



There are other factors that are related to QLCS maintenance. These factors (as previously noted in AWOC IC Severe 2 lesson 3) have been found to encourage downwind propagation:

(1) Rich boundary layer moisture --- Moisture-rich air fosters new storm development by lowering the LCL and enhancing precipitation drag

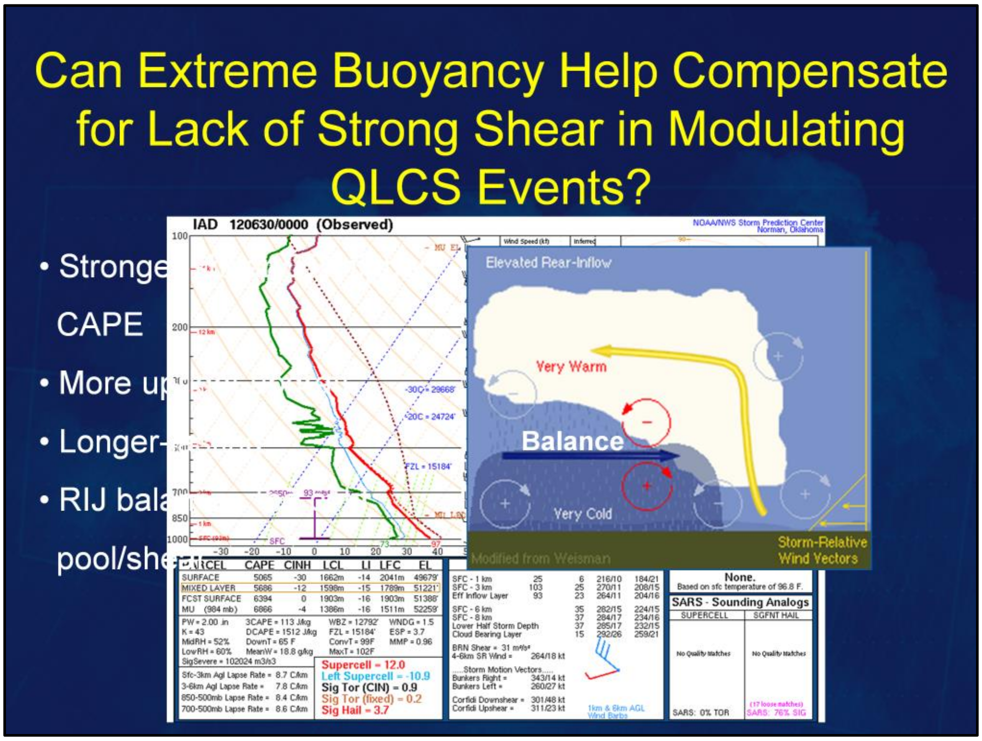
(2) Steep low-level lapse rates --- Steep lapse rates enhance both CAPE and downward momentum transfer

(3) Minimal Convective Inhibition or CIN --- The potential for storm initiation is maximized when CIN is low

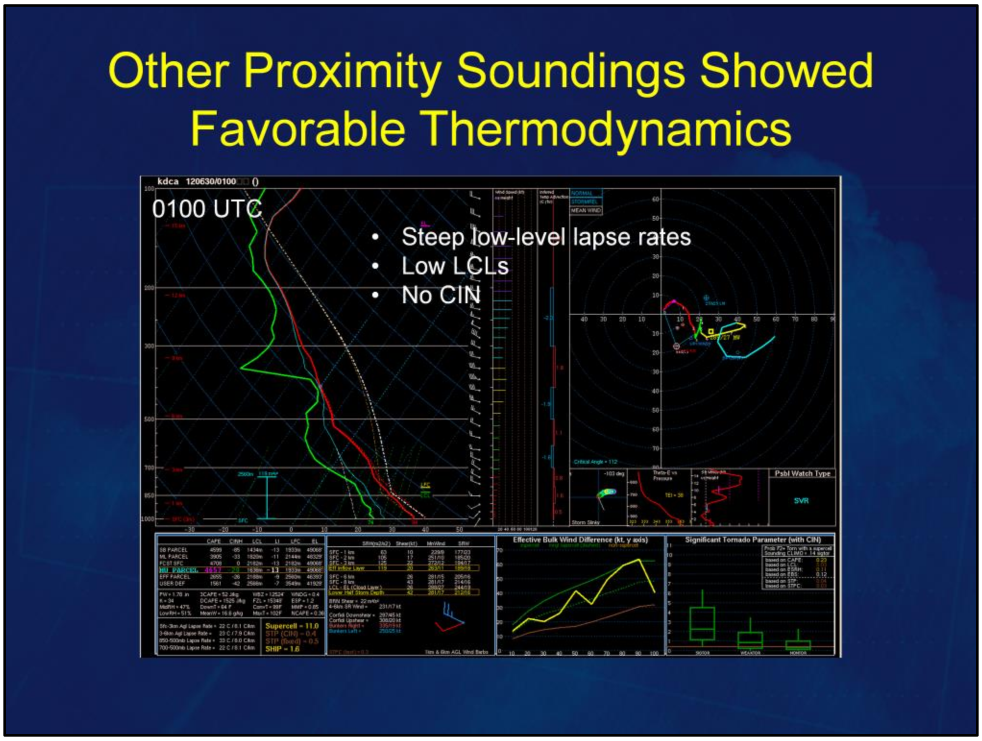
(4) Fast cloud-layer flow --- Fast flow increases gust front speed by strengthening storm outflow; fast flow also fosters the development of embedded supercells and their associated severe threats

(5) Deeply *unidirectional* flow --- Unidirectional flow encourages elongation of the system cold pool in a preferred direction, thereby enhancing storm-relative inflow in that direction

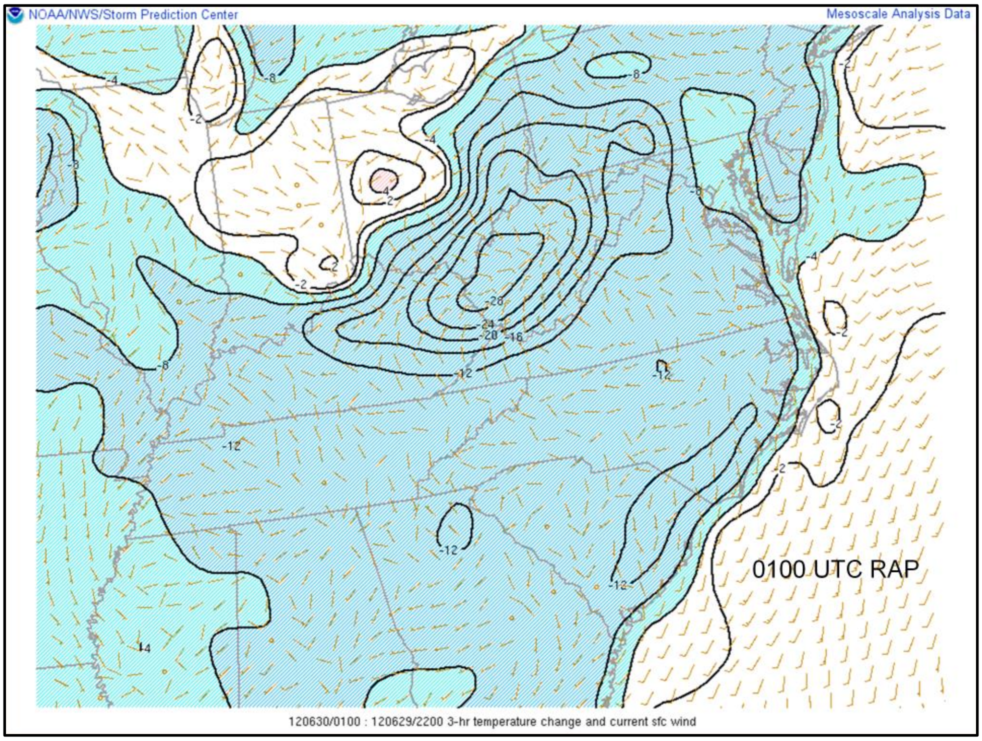
(6) Slightly-backed near-surface winds relative to the mean flow --- Backed low-level winds enhance storm-relative inflow and the rate of downwind cell development



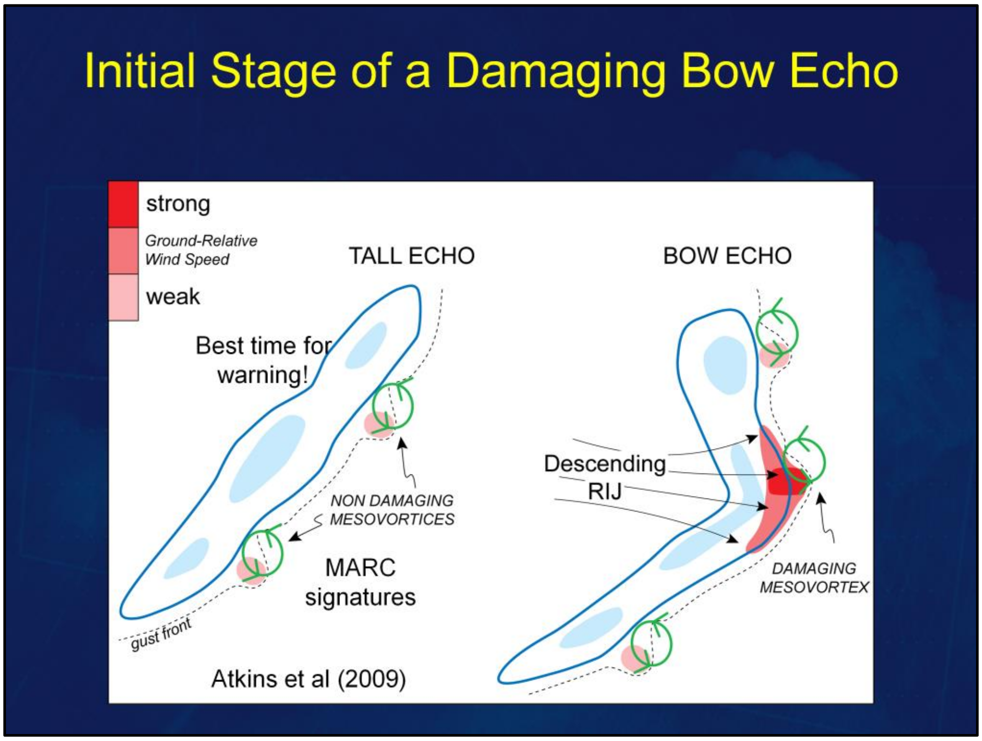
Based on the 00z IAD sounding, there was over 5000 J/Kg of SBCAPE. Corfidi forward propagating vector = 301 deg/48 kts. DCAPE from the observed sounding was 1512 J/kg. Some other forecast soundings had close to 2000 J/Kg of DCAPE. So, shear was not impressive but CAPE was huge, leading to a strong and deep cold pool. In RKW theory, if the shear is weak, a cold pool/shear balance is achieved with the RIJ which seems to allow the system to last a long time. Let's look a NSHARP AWIPS-2 sounding which points to some more details.



From a 0100 UTC RAP sounding for DC, there are steep lapse rates, low LCL, no CIN.



Due to the extreme instability out ahead of progressive derechos, there can be some large, temperature contrasts which are indications of the strength of the cold pool and subsequent strong wind potential. By 0100 UTC, the analysis showed temperature drops of greater than 26F due to the QLCS cold pool.

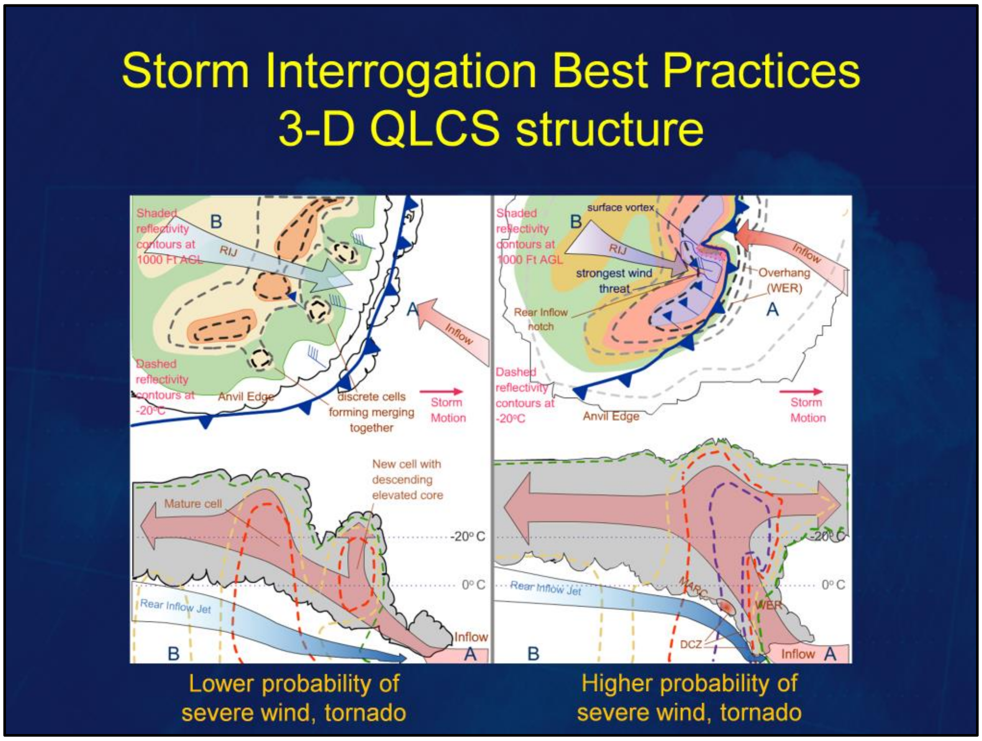


The initial stage of a bow echo at the onset of severe damaging surface winds is a time when the precipitation area is not bowed out. An updraft surge occurs which then produces a severe downdraft. At the same time, anvil debris typically spreads rearward of the main convective line with respect to the steering layer flow. The anvil debris acts to initiate the rear inflow jet (RIJ).

In anticipation of the bowing phase, the best time for initial warnings is in the tall echo stage when updraft surges occur , prior to the onset of the RIJ and severe downdraft winds. This is when you typically see strong, deep convergence, represented by the MARC (Mid Altitude Radial Convergence) along a segment of the line.

Just before the bowing stage, the descending RIJ hits the ground and begins to push forward. The most severe mesovortices may form at this time. The most severe surface winds occur when the mesovortex forms near the apex of the RIJ.

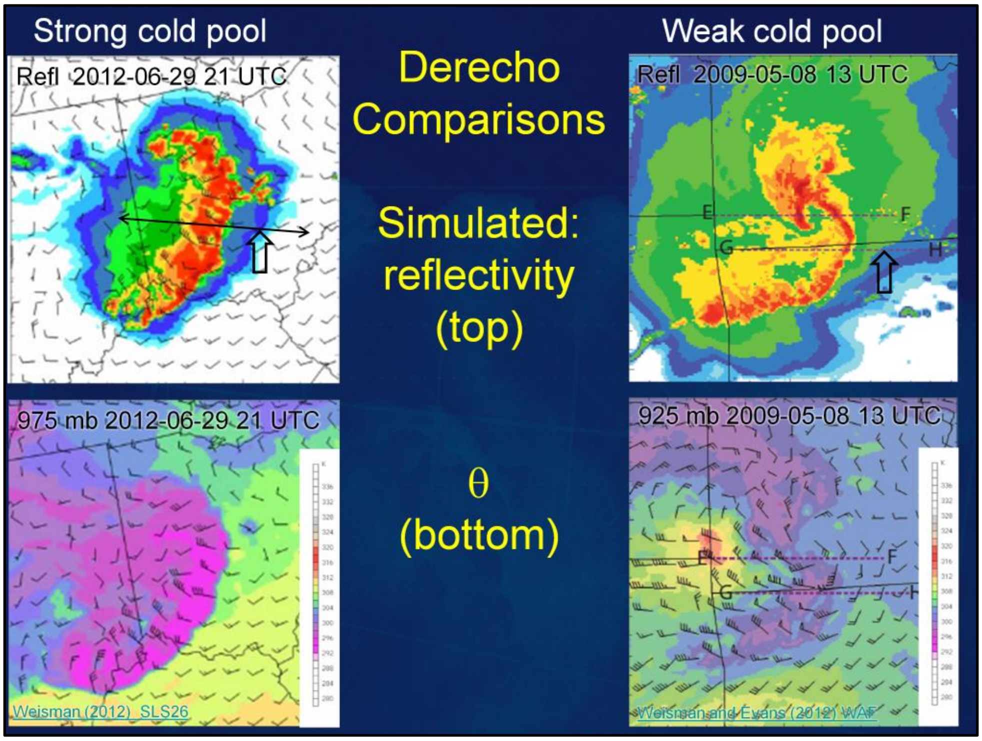
As the convection morphs into a bow echo, the updraft depth often decreases, and a rear to front dry slot forms. The strong outflow from the RIJ becomes firmly established and typically has already been on the ground for some time.



This next section is from IC Severe 3, a lesson produced with Jim and Ron P. on QLCS Storm-interrogation, first published in 2010.

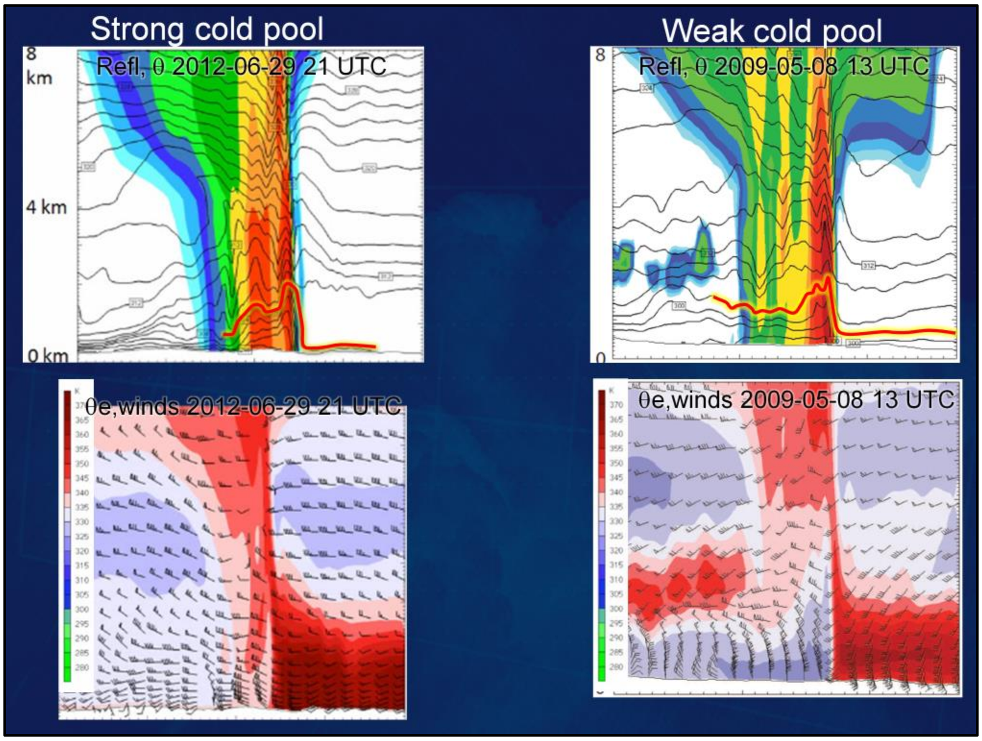
The most severe QLCS events typically have an upright updraft with almost slab-like appearance along a deep gust front. The convection is able to remain attached to the gust front and so on radar, you may not actually see a separate fine line from the intense reflectivity cores. A deep convergent zone accompanies the gust front. On some occasions, and after accounting for system motion during volume scanning, you may see a strong echo overhang leading the reflectivity core. Rear inflow notches signify intense RIJ channels. The RIJ remains elevated to descend only immediately behind the convective line. Lightning often precedes the arrival of the line. Mesovortices are common with these structures as there is plenty of deep updraft over their formation regions.

The less severe events exhibit more isolated convective cells often displaced well behind the gust front. A separate fineline is often visible ahead of the first reflectivity cores. The gust front is often severely sloped with a shallow leading edge. The RIJ often descends well behind the leading convective cores. Deep, severe mesovortices would be extremely rare with a sloped system like this.

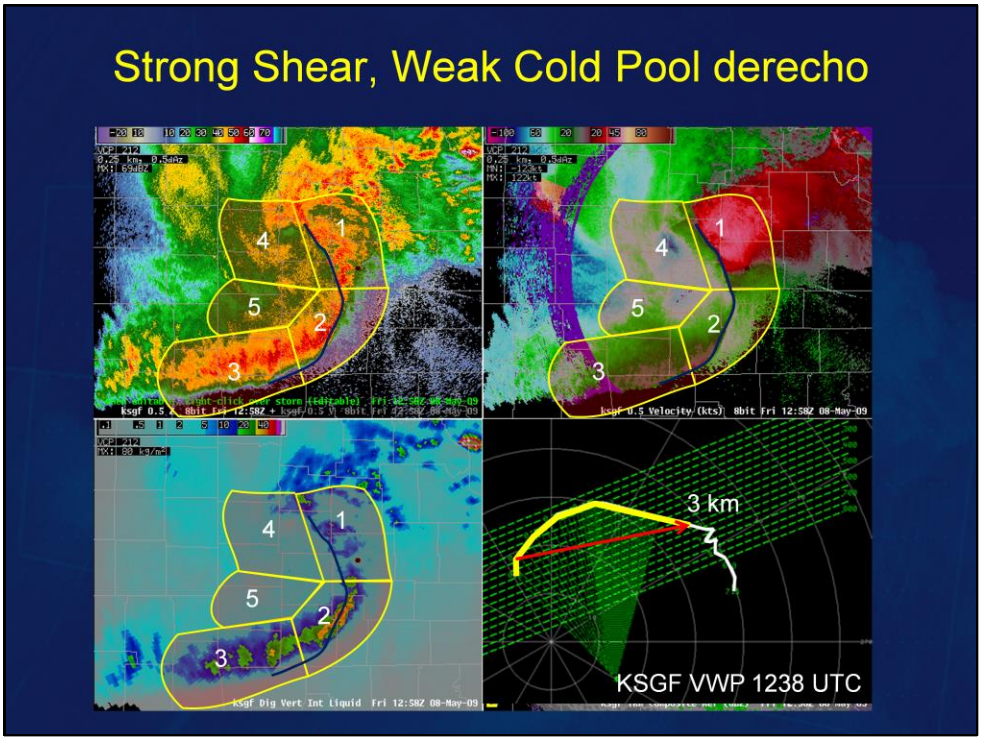


There are subtle, but important, differences even amongst QLCSs with slab-like lifting. To illustrate, here is a comparison between the infamous 29 June 2012 derecho and the Superderecho of 08 May 2009. Both derechos are similar in age but differ in the strength of the cold pool. Consequently their structures differ as well as the locations and types of hazards. The most typical structure is the one represented by the 29 June 2012 event here in Ohio. Note that the cold pool dominates its organization with temperature deficits ranging to 10 to 13 deg C. We find a large region of strong winds whose components are typically normal to the gust front with the highest values immediately behind. A poorly defined comma head of high reflectivity appears on the north side and a pool of surface-based vorticity lies along the gust front to its north and east. The midlevel representation of this vorticity is stronger and lies rearward over the low-level cold pool. As such there is no surface representation of this MCV. The more unusual structure came from the 08 May 2009 case where a much stronger bookend vortex appears in the reflectivity. This derecho's cold pool is much weaker with a temperature deficit of only 4 to 6 deg C. In this case, there is a well defined low-level vortex directly inside the reflectivity comma head. The strongest winds now don't lie just behind the gust front but instead are more focused around the west to south sides of the vortex. Essentially the loss of the cold pool allowed the MCV's pressure minimum to reach the surface and create a hurricane-like warm core low.

These plots are courtesy of successful 3 km WRF runs that simulated the structures of both derechos studied by Weisman (2012) for 29 June 2012 and Weisman and Evans (2012) for 08 May 2009.



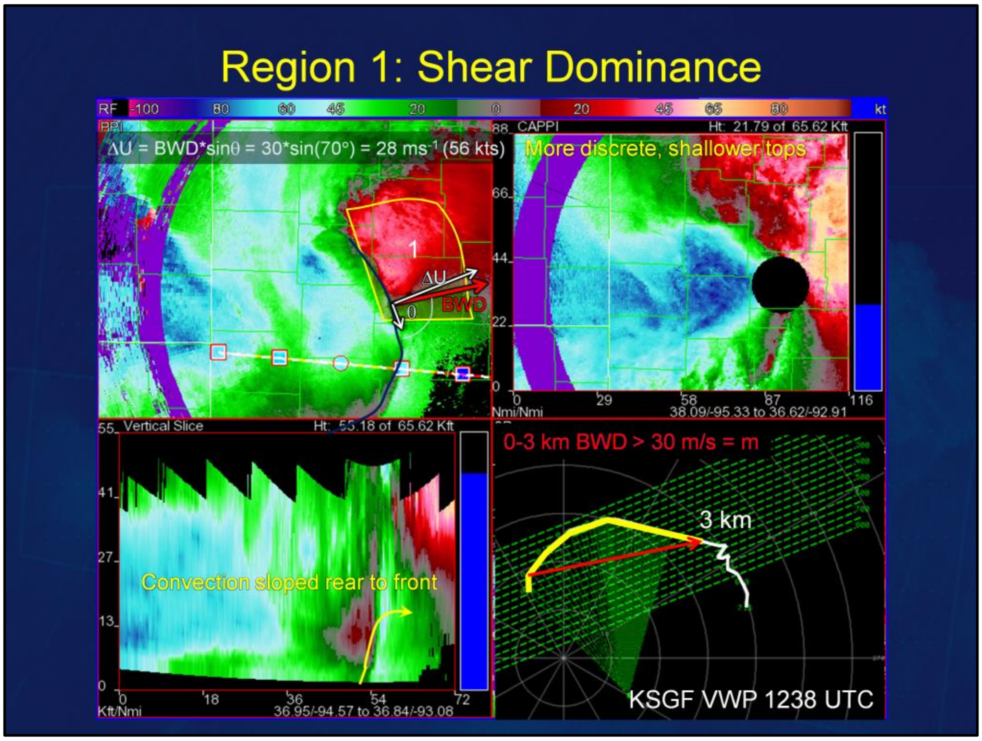
When we look at the cross-sections, we see that the strength of the cold pool (seen by the rise in isentropes in the top panels) is much higher for the 29 June case in Ohio whereas there's a much smaller rise for the 08 May event. So what did the environment do to create such a radical difference in structure. One possibility is that the 29 June case featured much higher θe in the pre-storm boundary layer, but weaker shear. Notice the rather weak pre-storm wind profile for 29 June vs. 08 May. However other important factors include those that could've weakened the cold pool in 08 May and one of these may include higher boundary-layer relative humidity.



A strong derecho with a relatively weak cold pool, such as May 8, produces several regions of interest affecting your warning decisions, regions 1-5. In region 1, the midlevel shear induced by strong low-level inflow and MCV-enhanced midlevel winds, has caused the convection to tilt downshear and become fragmented and somewhat shallow as seen in the DVIL product. The gust front follows the fragmented convection. In region 2 the vertical shear in the pre-storm air has become balanced with that at the cold pool boundary and the convection has become upright and deep (see the DVIL product). The gust front lies on the leading edge of a solid line of heavy convective precipitation. Down to region 3 and here the gust front has begun to pull ahead of the convective line. The DVIL product again shows shallower convection. All of these structural changes have big implications for the warning strategies and much of it is related to the orientation of the cold pool boundary with the pre-storm vertical shear.

The fourth region has much to do with what we talked about before regarding the MCV penetrating to the surface and allowing a warm-core vortex to generate strong circulating winds around the low pressure. The weakened cold pool allowed this to happen. Region 5 represents the more traditional rear inflow jet and an axis of high winds trailing well behind the gust front.

We'll take a closer look at these regions, what they mean for warning strategy and how to identify them coming up.

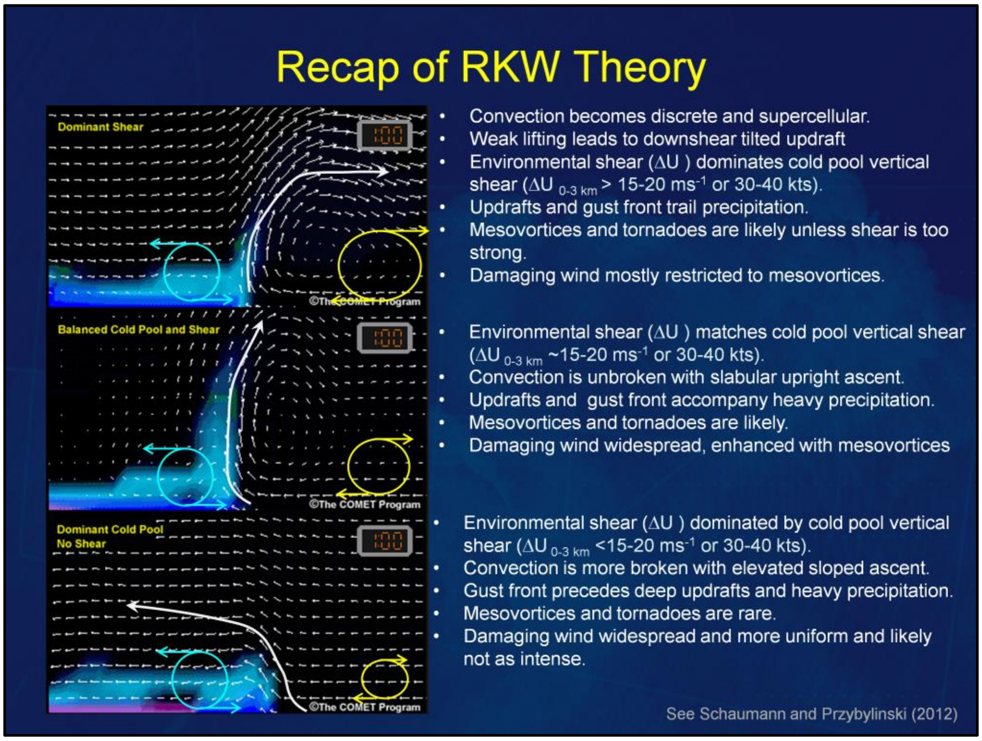


This is a region where the gust front spawns relatively discrete convective cells whose tops are sheared rear to front (relative to the cold pool) and the updrafts are somewhat shallow. Going back to the shear we can see why. We overlay the 0-3 km shear vector across region 1 and then the location of the cold pool boundary. The 0-3 km bulk wind difference is 30 m/s. But we notice that the shear vector is not exactly perpendicular to the boundary; instead there is a 70 degree angle. Thus, the component of the total shear is rather 28 m/s. This is an unusually high value that is responsible for the character of the convection here.

What does this mean for you at the warning desk? Take a look at the velocity and you'll see the gust front in this region occupied by strong horizontal shear. The discrete convective updrafts were rooted to the gust front and quickly broke up into supercell-like structures as a result of this strong line-normal vertical shear. Mesovortices formed within these updrafts. However their formation may have been more akin to that of traditional supercell mesocyclones. Multiple tornadoes formed in this region shortly after this radar scan.

As a warning forecaster, when you see the gust-front normal component of the 0-3 km shear exceed roughly 15 – 20 m/s, watch out for convection to become discrete and for mesovortices or supercellular mesocyclones to form. Tornadoes are likely if at least 10 m/s of that shear is within the 0-1 km layer in the presence of other favorable thermodynamics that were covered in IC2.

Why does the convection become so discrete and somewhat shallower in the face of stronger shear? We'll revisit the theory of shear vs cold pool balance.



The importance of vertical shear and its balance with the cold pool goes quite a ways to explain the structural characteristics of derechos and likely hazards. All derechos produce damaging wind (by nature of the definition), however, the presence of mesovortices can change the intensity and shape of the severe winds.

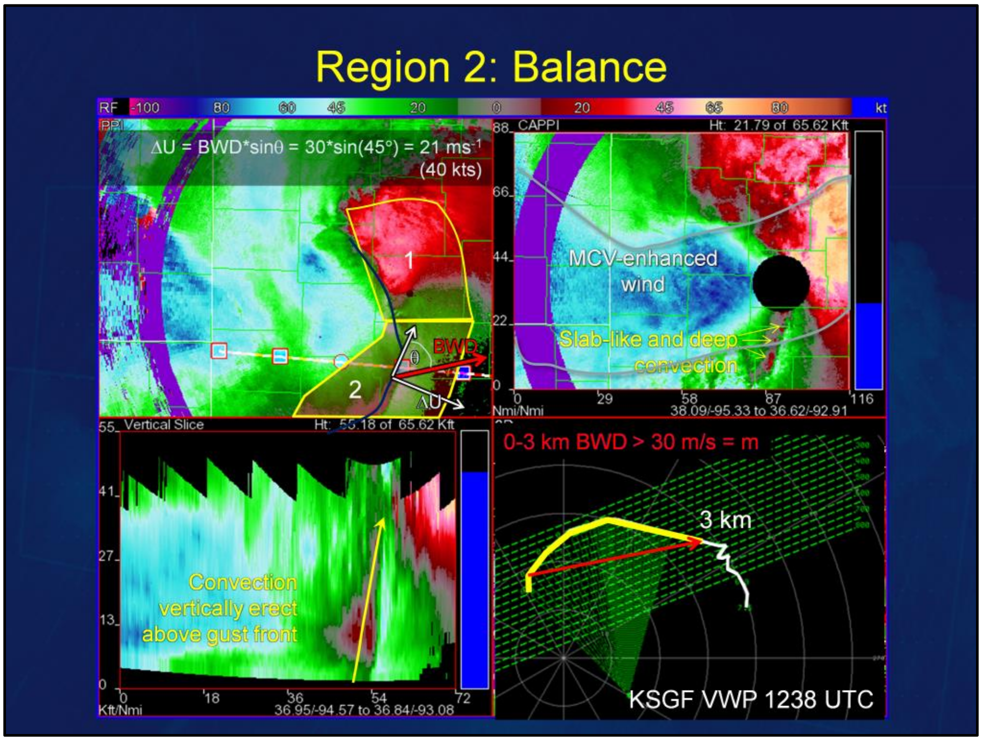
We just saw an example of a shear-dominant segment of the gust front where more discrete, shallower convection led the gust front. The imbalance between the strong environmental line-normal shear and weak cold pool shear led to weak lifting as updrafts are quickly tilted downshear. The value of delta-U we got 28 m/s fell into the shear dominant regime. Mesovortices or supercellular mesocyclones are likely unless the shear is strong enough to completely shred updrafts. Tornadoes are likely contingent on favorable thermodynamics and 0-1 km shear. Damaging winds are not going to be widespread, but mesovortices will likely have some.

Decreasing the environmental vertical line-normal shear into the 15-20 m/s range will lead to a more balanced state given the same cold pool strength. When this happens then the ensuing updraft along the convergence zone strengthens and becomes more erect. The gust front lies underneath the updraft and immediately in front of the heavy convective precipitation. This regime allows for almost unbroken convective updraft above the gust front. Mesovortices and tornadoes are all likely in this regime, the latter contingent on favorable thermodynamics and sufficient low-level (0-1 km) vertical shear. Damaging wind is also likely to be widespread thanks to the unbroken convective line.

As the environmental line normal vertical shear decreases further below 15 m/s, or the cold pool strengthens, the convective updraft is likely to slope front to rear. Now the gust front begins to race out ahead of the line of convective precipitation. The slab-like lifting may become more broken and much of the ascent will be elevated above the cold pool. Mesovortices become rare, and so do tornadoes, no matter the actual value of the environmental vertical shear. The only way to improve the line-normal vertical shear is for part of the line to surge forward producing a more favorable orientation to the convective line.

Even with this imbalance, derechos are possible. This dominant cold pool regime can occur in parts of a curving derecho producing QLCS or the entire QLCS could be cold pool dominant.

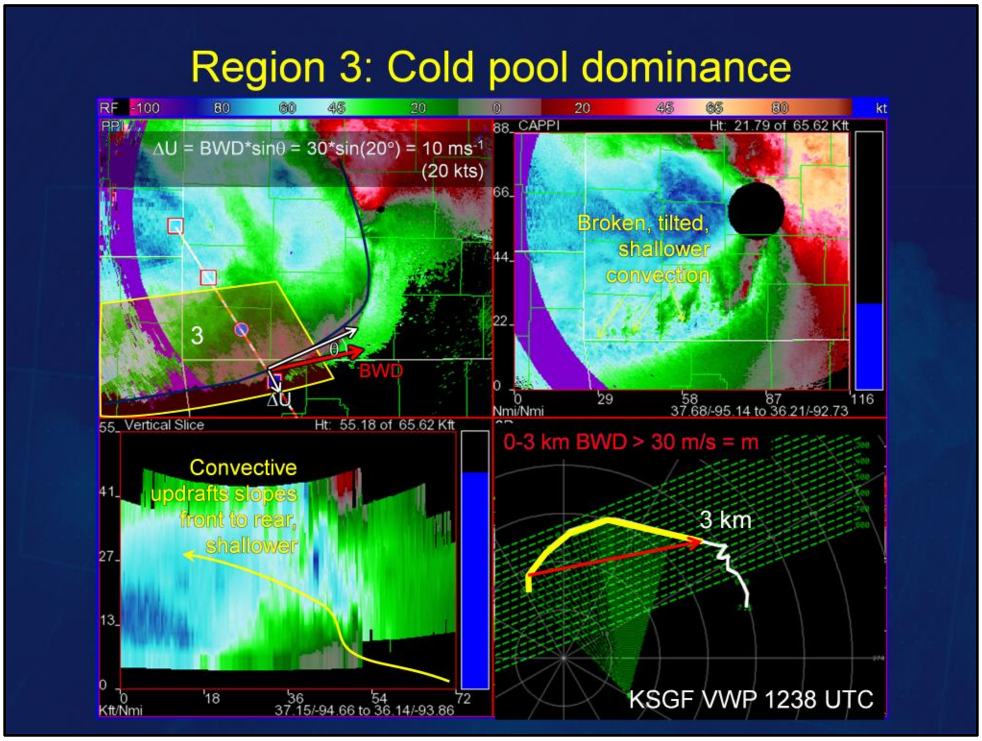
Let's take a look at the other regimes of the sample derecho.



The gust front changes orientation further south from region 1 such that it's oriented NE to SW. Let's assume the 0-3 km BWD is the same in region 2 (a dangerous assumption to be mentioned later). In this new location the environmental shear vector is oriented roughly 45 degrees to the gust front. This results in a delta-U of 21 m/s. This new orientation is closer to the typical values associated with 'balanced' systems. The visual manifestations are obvious as the convection is deeper, more slab-like (continuous) and vertically erect. The velocity data shows a deep convergence zone in the cross-section that extends along a line exceeding 21 kft ARL in the CAPPI. That's impressive!

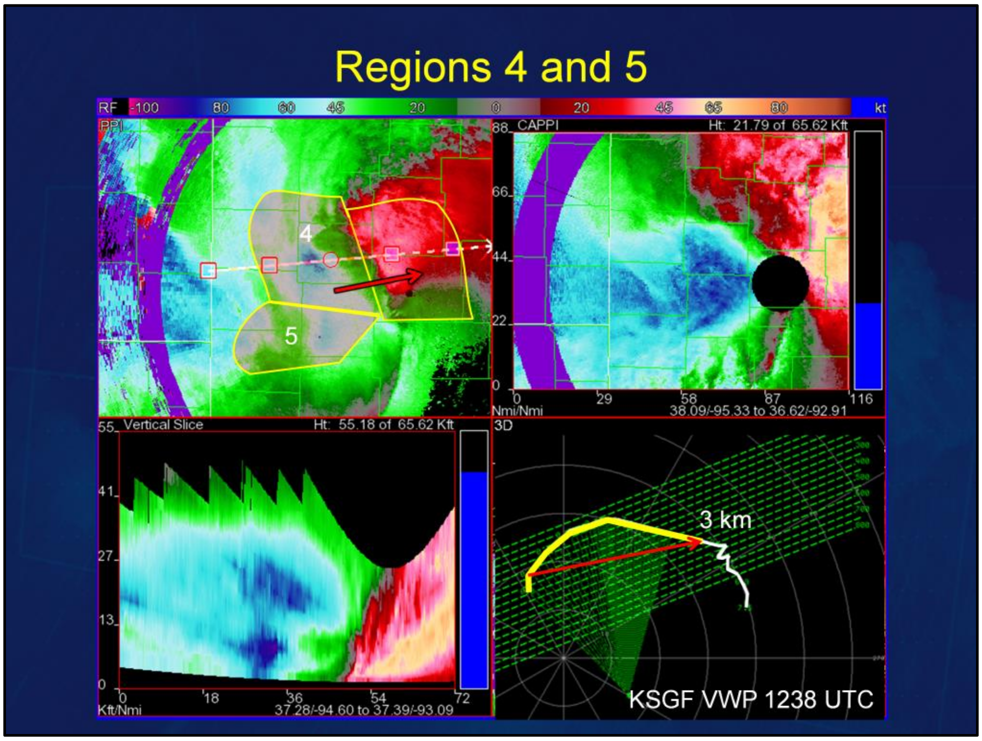
This region is likely going to contain widespread damaging winds along with focused regions of enhanced wind damage with mesovortices. Watch this area carefully for mesovortices that may also strengthen enough to become tornadic.

So the delta-U appears somewhat large and yet the radar data shows deep upright slab-like convective line that suggests balance. If the RKW theory is correct, then either the cold pool is unusually strong to create balance with the delta-U, or the delta-U is smaller. We've seen a strong suggestion from the model data that the cold pool isn't any stronger in region 2 and so we can rule that out. But what about the delta-U? Well it could be weaker. One possibility is that the environmental BWD is somewhat weaker here because this location is somewhat south of the strongest mid-level flow wrapping around the convectively-generated MCV. Note in the 21 kft velocity in the CAPPI there is a zone of very strong winds with a rather sharp southern edge. This edge appears to be on the north side of region 2. It is possible that weaker midlevel flow to the south may contribute to weaker environmental vertical shear and thus a higher chance of a shear/cold pool balance.



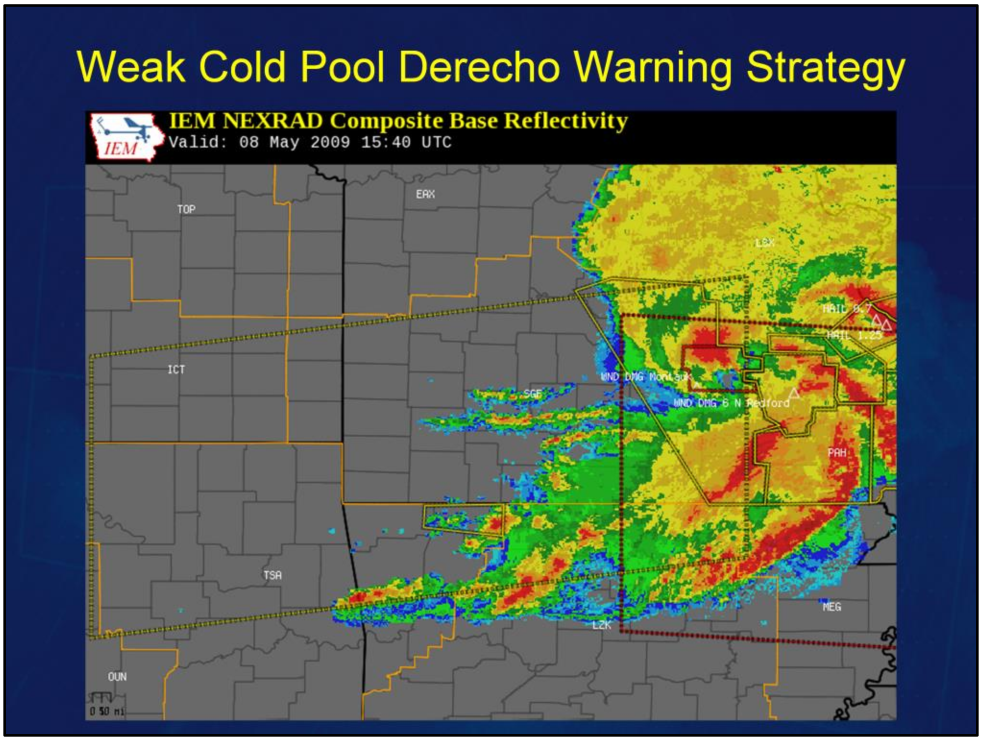
On to region 3 and the gust front orientation (WSW-ENE) rapidly diminishes delta-U. Playing a conservative stance and plugging in a 20 degree difference between the BWD direction and the gust front orientation yields a delta-U of 10 m/s. That's less than the typical optimal values of 15-20 m/s and thus this segment of the derecho should feature a cold pool dominant structure. Indeed the radar shows that with diminished reflectivities at 20 kft and in the cross-section also shows the same. The velocity shows the gust front position extending further ahead of the convective line and the line itself appears more broken in the CAPPI.

This is the region where mesovortices and tornado threat is minimal, not worth a tornado warning. Wind damage is certainly possible though this area is typically south of the RIJ and so the wind is likely not as widespread as directly ahead of the strongest portion of the RIJ.

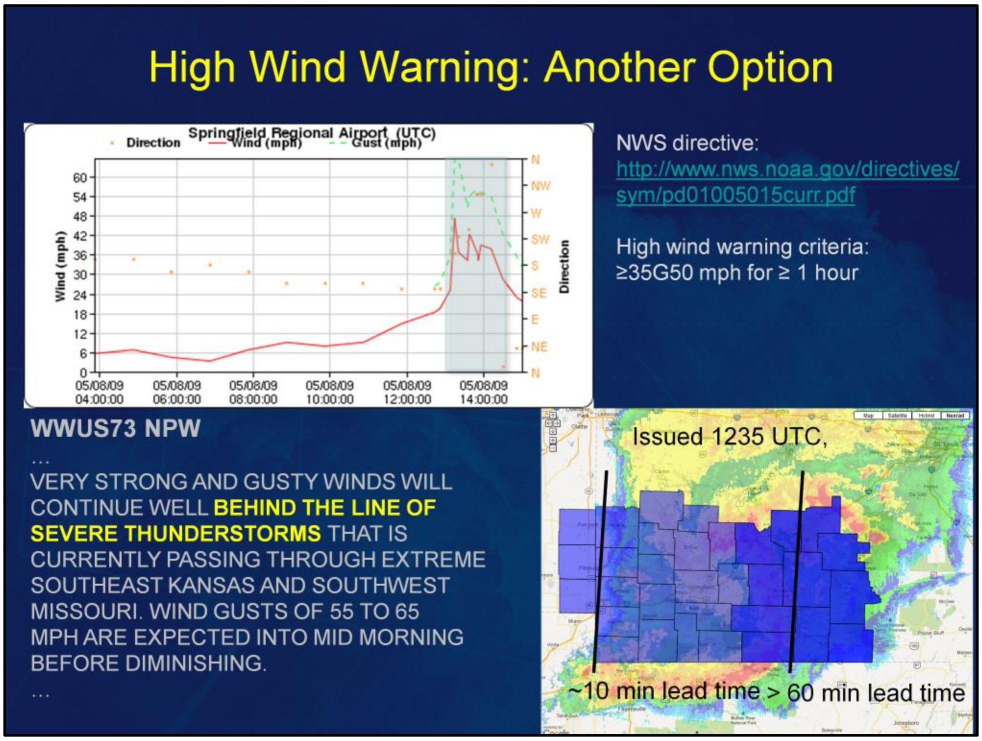


Going back to the northwest we see what made this derecho so special. The weak cold pool allowed the low pressure associated with a powerful midlevel MCV to be reflected at the surface. The result was an intense circulating wind storm around a meso-β vortex. Thus, a wide area of hurricane force winds formed around the vortex center in region 4. The radar could see this circulation because it was deep. Most of the time the cold pool would limit the lower extent of this circulation above a shallow layer. But not this time. What complicated the situation was the presence or introduction of mesovortices along the curling convective band towards the MCV. Some of these were tornadic.

Region 5 represented the more traditional region of the rear inflow jet axis. This is a nearly ubiquitous feature in derechos. However the RIJ in this case was certainly influenced by the presence of the MCV. Both of these areas produced severe winds requiring a warning. But what type of warnings should be issued? After all, some of these winds lasted for more than 20 minutes and were not necessarily associated with active convection, especially in the southern portions of region 4 and region 5.

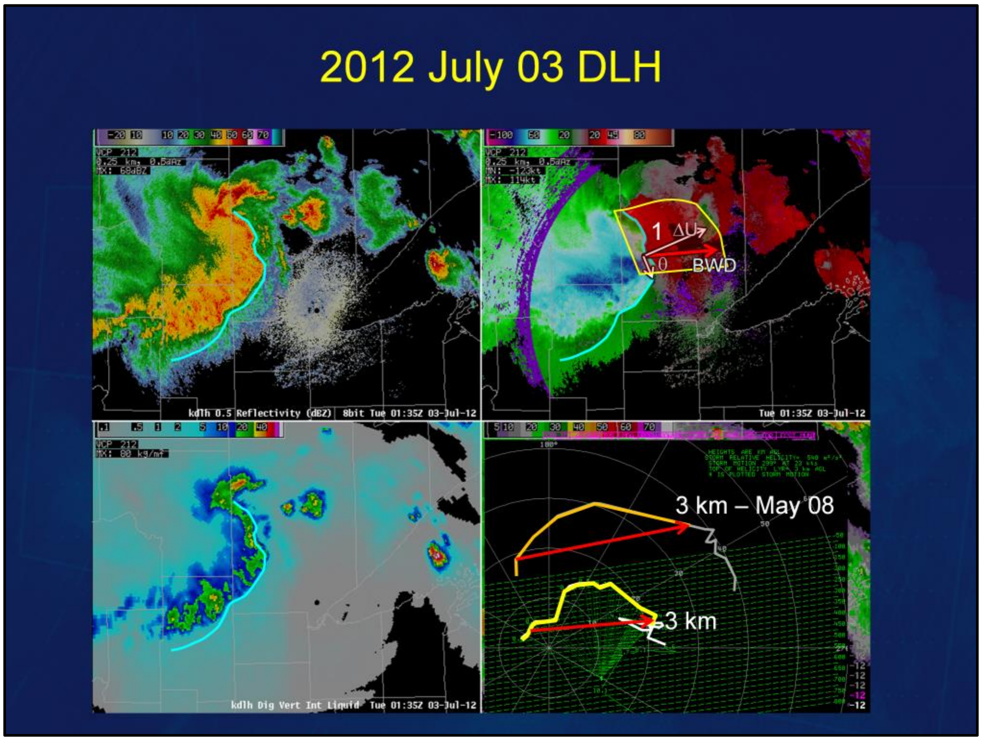


If this derecho were a tropical cyclone then the answer would be that either high wind warnings or an inland hurricane wind warning would be issued. But this is an organized thunderstorm and so traditional severe thunderstorm warnings were issued with the occasional tornado warning to address that threat. Notice that severe thunderstorm warnings covered much of regions 4 and 5 as the MCV and RIJ began to produce severe winds. Yet the high winds in much of these regions were not associated with audible thunder, especially just south of the MCV center where descending air eroded precipitation.



Perhaps a high wind warning would also be an option to cover those areas of damaging winds that are not also experiencing active convection. There are criteria that have to be met including high winds at 35G50 kts or more lasting for at least an hour. The meteogram from KSGF on that day shows indeed that such criteria were met. In fact, the Springfield office issued a high wind warning just ahead of the derecho as it became apparent that it was becoming a big show. The text in their warning described that the winds would occur behind the severe thunderstorms. However the final winds were significantly stronger than anticipated. This is understandable since this event was rare. Rare, but not unprecedented. Other derechos have also been cold pool deficient with severe (hurricane force) swirling winds around an MCV including one famous event on 2003 July 21 in NW PA and W NY.

As you can see this derecho was widespread, but the worst of the wind damage from the combined RIJ , MCV, and downbursts was from MO to southern IN. Do notice that the derecho was responsible for significant flash flooding too as a result of slow moving convection ahead of the MCV and then the intense convection on the north side of the MCV. Much of the worst wind damage resulted from sustained hurricane force winds over a period of an hour. This duration is what makes the derecho potentially more damaging.

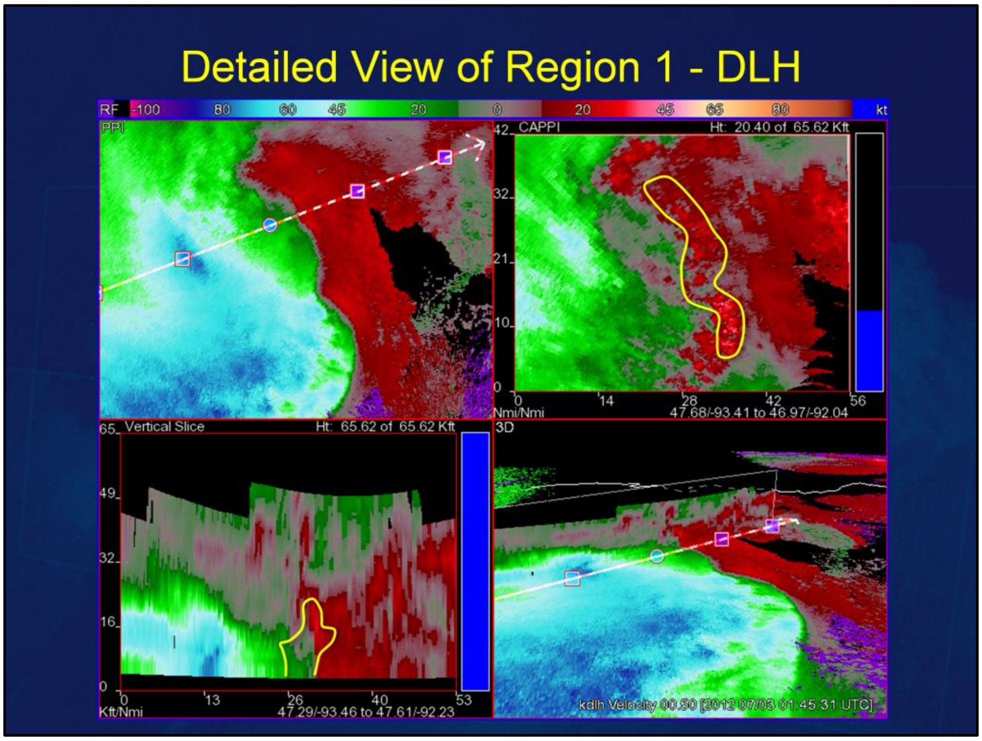


The majority of derechos don't transition into a cold pool deficient state. Instead they appear much like this one did west of Duluth, MN on 2012 Jul 03. The shape is the same as the derecho of 2009; it's that of a large bow with a bookend vortex to the north. But the differences begin when you notice that the most solid portion of the line (see DVIL) is now north of the apex. Notice that now the cold pool boundary is leading the heavy convective precipitation everywhere, but is adjacent north of the apex and is well separated to the south.

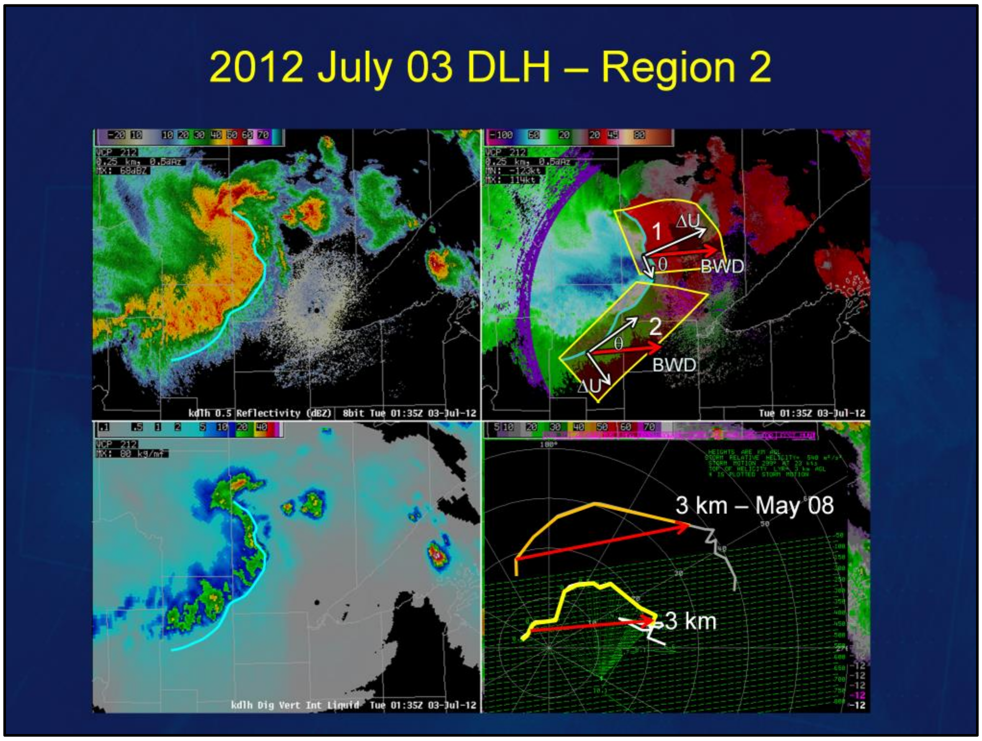
This structure makes sense as the hodograph from the KDLH VWP shows a weaker 0-3 km shear even though it's from the same direction. The weaker shear means the cold pool has an easier time to at least achieve balance north of the apex in region 1.

As a result, this derecho is somewhat less complex than the one on 2009 May 8.

The MCV is apparent but not as intense, and it is uncertain as to whether it extends to the ground. However the RIJ appears strong with inbounds at 2-3 kft ARL reaching 80 kts. In addition, a developing mesovortex is located on the north side of the RIJ apex along the cold pool boundary.

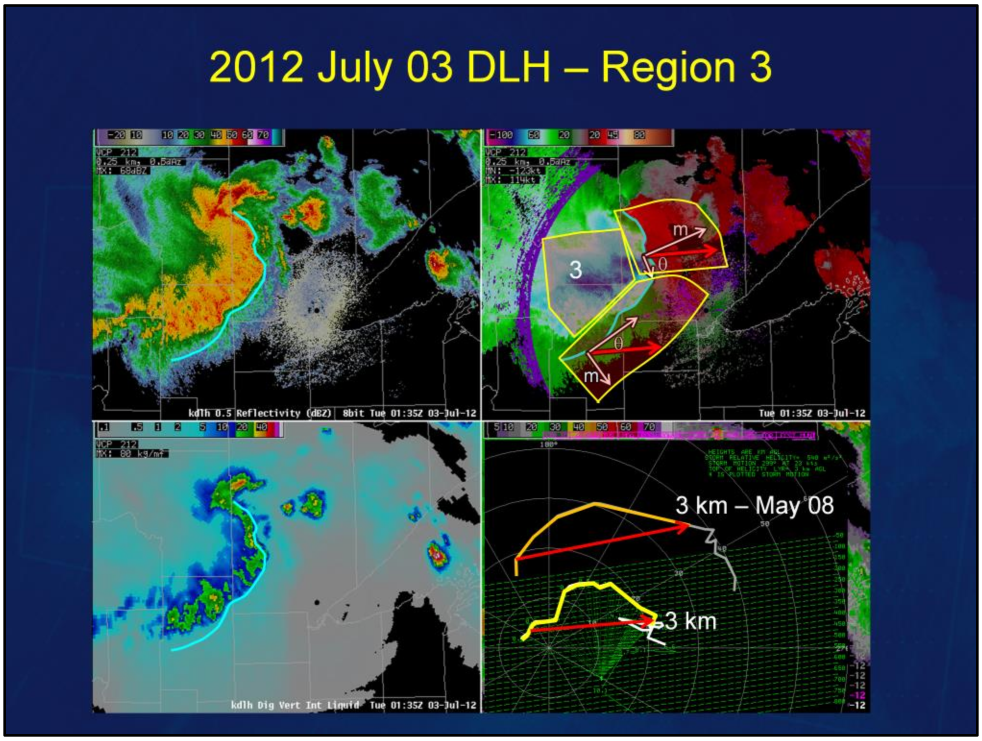


Zooming in, see that the cross section shows vertically erect strong echoes in this region 1, the strongest is with an isolated cell well out ahead of the line and along a warm front. Along the convective line, an almost unbroken line of ZDR columns at 20 kft ARL highlights the almost slab-like lifting occurring over the low-level outflow boundary.



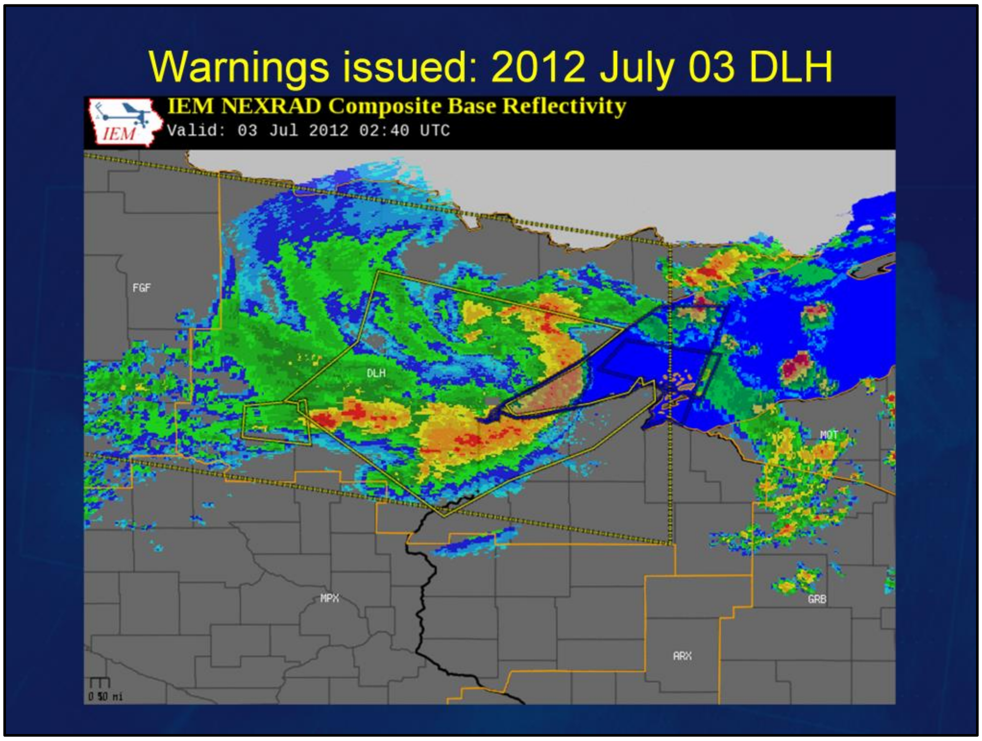
In region 2, the orientation of the gust front reduces the boundary-normal shear (m) far enough that the cold pool dominates. In this case to the point where the cold pool boundary outruns the convective cores and the lifting becomes more sloped with less slabular lifting and more discrete deep updrafts. As a result, this derecho is somewhat less complex than the one on 2009 May 8.

The MCV is apparent but not as intense, and it is uncertain as to whether it extends to the ground. However the RIJ appears strong with inbounds at 2-3 kft ARL reaching 80 kts. In addition, a developing mesovortex is located on the north side of the RIJ apex along the cold pool boundary.



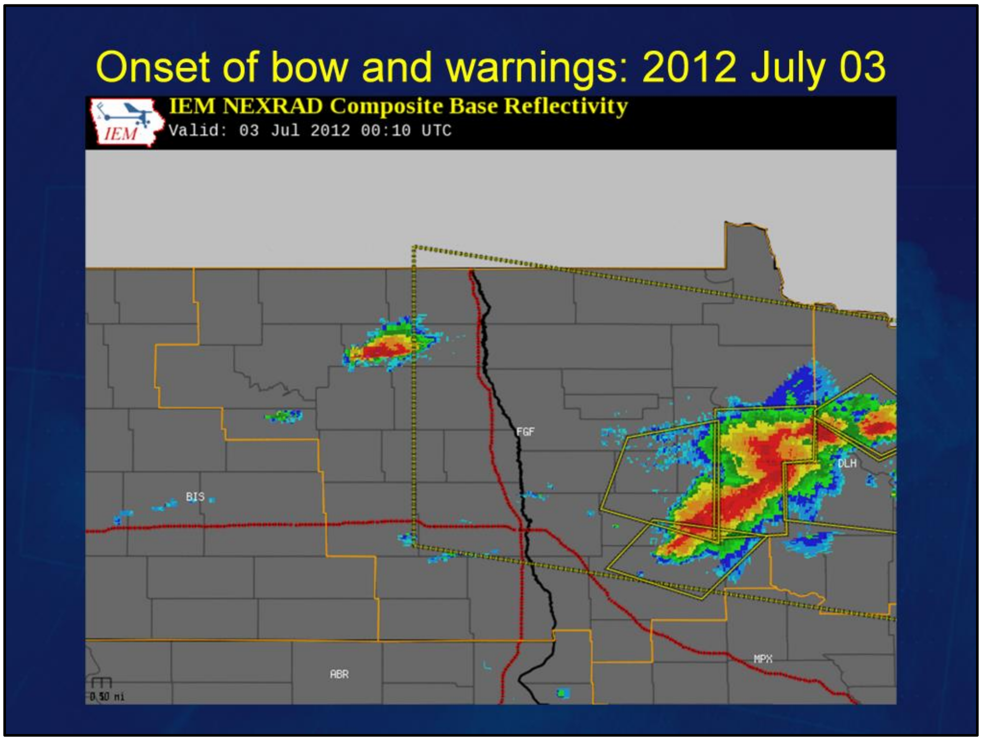
We label the RIJ south of the elevated MCV as region 3. The RIJ is sufficiently strong enough to cause damaging winds, especially in conjunction with local downbursts and mesovortices. However, it's unknown to what extent those winds remain damaging as one goes further behind the line. This uncertainty certainly affects the decision of whether or not to keep severe thunderstorm warnings behind the line or introduce a high wind warning. A high wind warning has the advantage of lead-time, but at the cost of a false alarm should the wind duration not verify. Severe thunderstorm warnings have the advantage of higher resolution, more appropriateness with a severe thunderstorm, but the cost is lead time.

As a reminder, these regions are not meant to represent suggestions for warning polygons. They are highlighting areas representing common structures. For a recap of the actual warnings issued, let's go on.

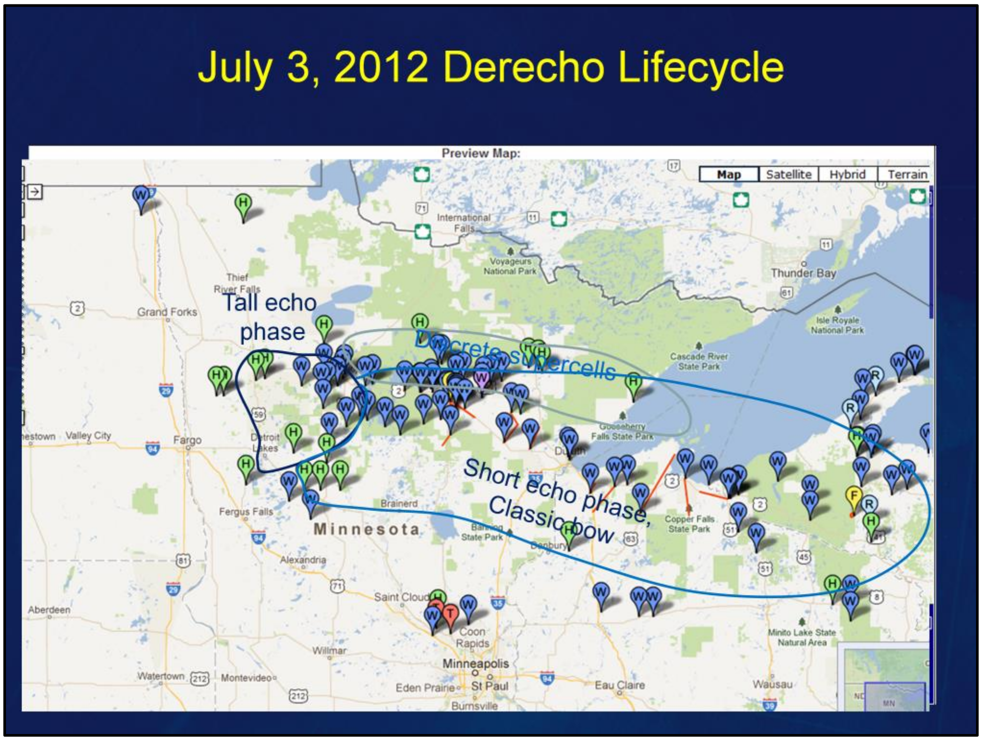


This is a Base Reflectivity mosaic radar loop of the derecho, beginning with the cluster of disorganized multi- and supercells east of Grand Forks near 00 UTC. The warning polygons were small to begin but the content of the warnings was definitely high end (excess of 80 mph, dangerous situation). The northern warnings focused on more discrete supercellular structures extending east of the developing bookend vortex. The southern warnings handled the primary developing derecho. By 0128 UTC, WFO DLH opted for one large warning encompassing the entire derecho. This strategy of laying out large severe thunderstorm warnings continued until the derecho exited their CWA.

The key here is to remember that the high end threat language began before the classic bowing shape of the derecho began.

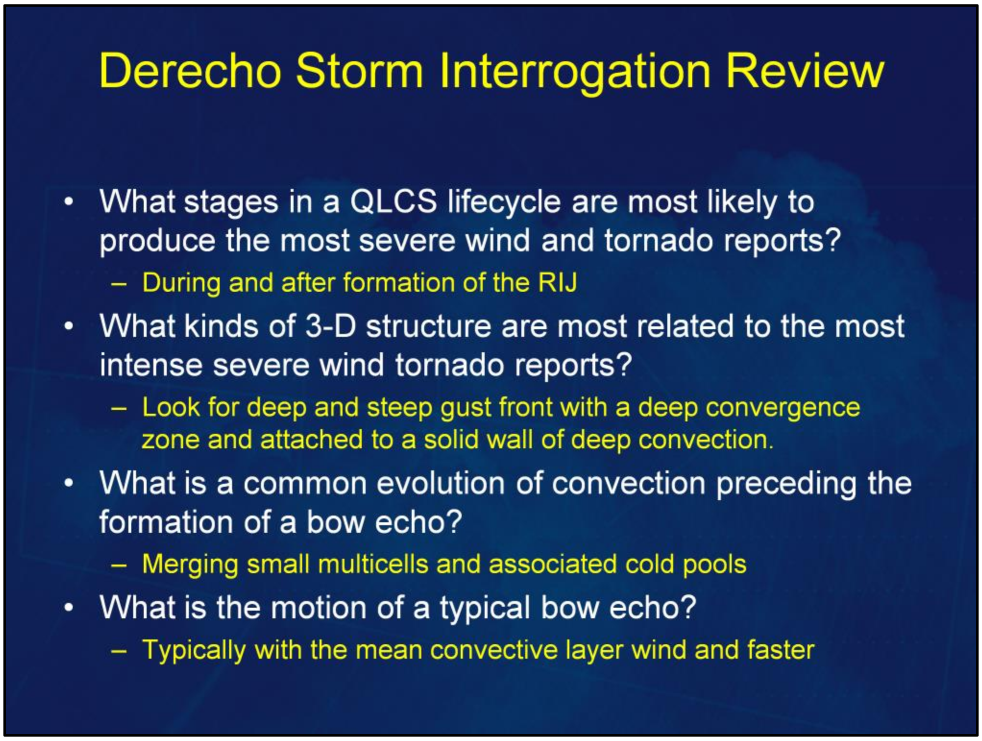


What did that beginning stage look like. Here it is when the updrafts started out more discrete and tall, but convective initiation became too aggressive and adjacent cold pools merged. At 2330 UTC was when cells merged across a region at least 100 km long. At this scale, and in an environment of high CAPE and strong shear, the merging cold pools strongly suggested the onset of a damaging bow. In less than an hour, the multicell cluster morphed into the classic bow of the derecho. But beforehand, the damaging winds were already well established.



Here is a composite of maximum expected size of hail (MESH) product taken from the NSSL on-demand site. At this beginning stage is when the updrafts are more discrete and tall and thus higher peak MESH values. The discrete supercells also appeared ahead and north of the bow along the warm front. The mature stage of the bow exhibited much shorter storm tops and thus the MESH shows limited values. This is why hail size is constrained quickly after the bow forms.

Supporting the theme from the composite MESH, the storm reports showed the typical transition from hail and wind in the tall echo phase to primarily wind in the mature, short echo phase of the Derecho. Then the reports of hail came in with the supercells leading the bow.



Which stages in a QLCS lifecycle are most likely to produce the most severe wind and tornado reports?

- During and after formation of the RIJ.

What 3-D structure is associated with the strongest severe wind and tornado events?

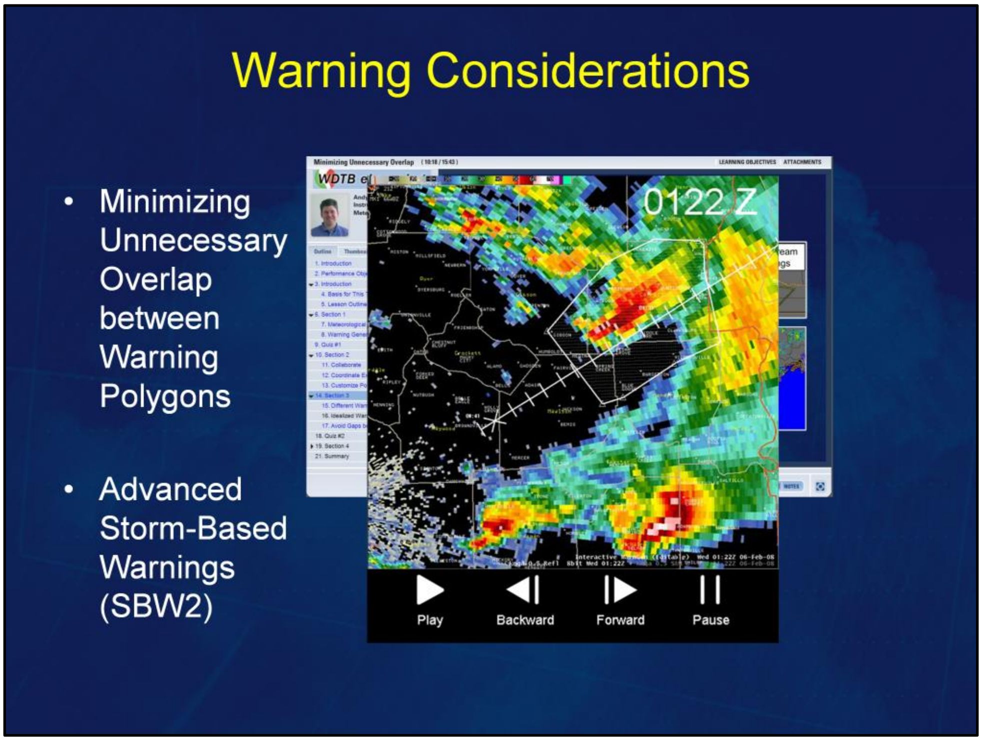
- A deep and steep gust front with a deep convergence zone attached to a solid wall of deep convection.

What is a common convective evolution preceding the formation of a bow echo?

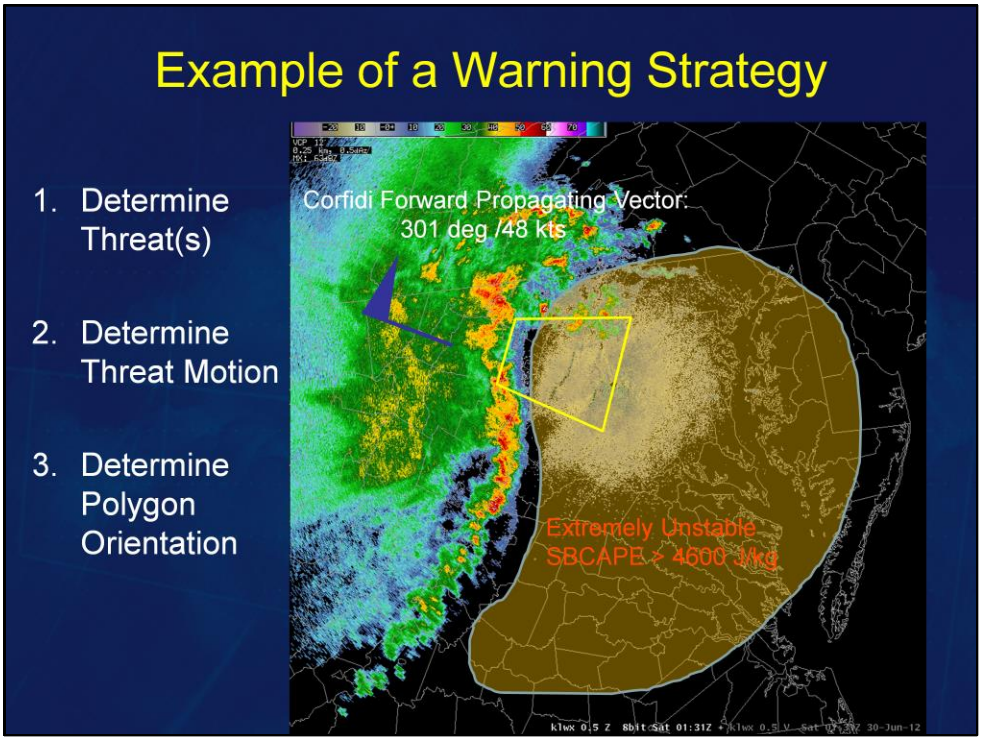
- Merging small multicells and their associated cold pools

What is the motion of a typical bow echo?

- Identical to the mean convective layer wind and faster



A fast-moving QLCS can present warning polygon issues for forecasters. During our Tornado and Severe Thunderstorm Warning Best Practices and Advanced Storm-Based Warning courses, we illustrated warning strategies for fast-moving storms, most of which were supercells. I will now present an example using the June 29, 2012 event on how to issue polygons for a fast-moving mature QLCS producing damaging winds due to a very strong cold pool in balance with a RIJ.



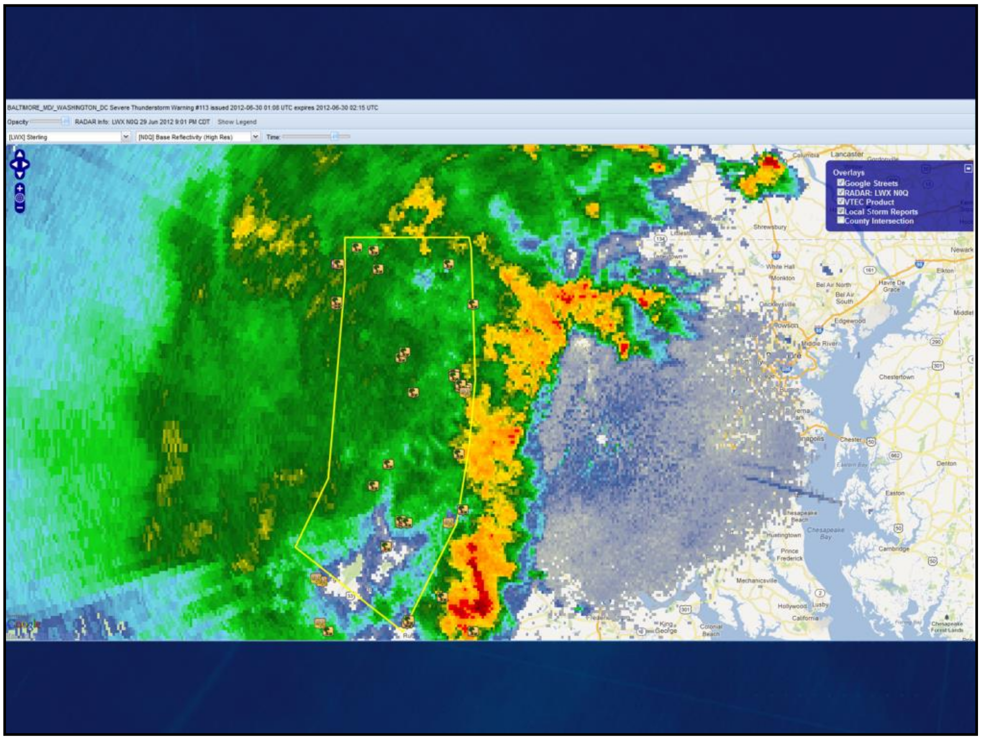
Here is a recommended warning polygon strategy for a fast-moving QLCS. This example is from the 2012 June 29 derecho.

Step 1 is evaluate the environment to determine potential threats such as tornado, wind, hail, and flash flood. As was discussed previously, this environment's main hazard was straight-line severe winds.

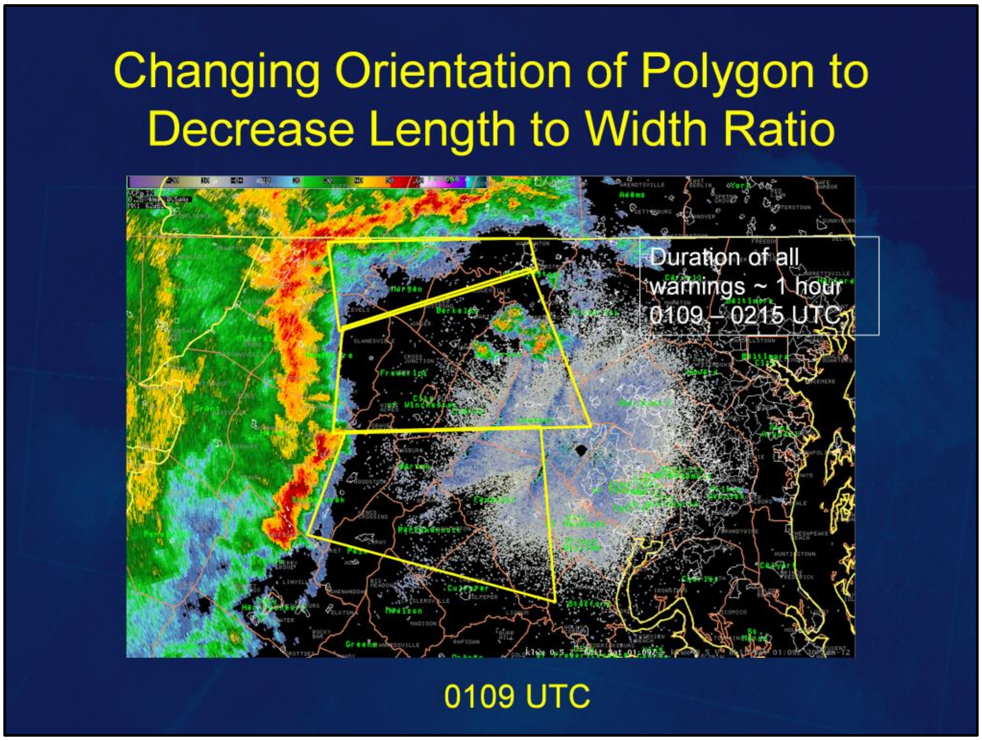
Step 2 is determine threat motion. Recall from the 00z IAD sounding, the SBCAPE was over 5000 J/kg and the 00z RUC forecast indicated that there was >4600 J/kg of SBCAPE ahead of the line across a large area. The NSHARP AWIPS 2 sounding (also available with BUFKIT) displayed a forward-propagating Corfidi Vector, which in this case was from 301 degrees at 48 kts (much faster than the 0-6 km mean wind). Unidirectional flow above the LFC is encouraging elongation of the system cold pool in a preferred direction, thereby enhancing storm-relative inflow in that direction. Because of extreme downstream instability and shear vector orientation, a strong, convectively-generated cold pool was contributing to a system-relative flow. All of this provides a good first guess approximation to the threat motion as shown.

Step 3 is determine polygon orientation and type. Mesovortex potential is low because the effective bulk shear is 35 kts and the QLCS is cold-pool dominant. Thus, our storm interrogation strategies will emphasize severe thunderstorm warning.

Steep upright updrafts are noted along the leading edge and there is a strong RIJ most pronounced behind the northern apex of the bowing segment as noted previously. Discrete cells are forming and merging along the leading edge of the reflectivity gradient with the gust front located just ahead of the gradient. The preferred warning strategy in this situation is to orient the polygons along the line of motion with a flaring out on the downstream end. Allow for some overlap to ensure adequate downstream lead time for locations on the entrance region of the polygon. And, if given the opportunity, within the constraints of workload warning management, it would be a good idea to break up the warning polygons to minimize excess text. The next few slides provide more detail.

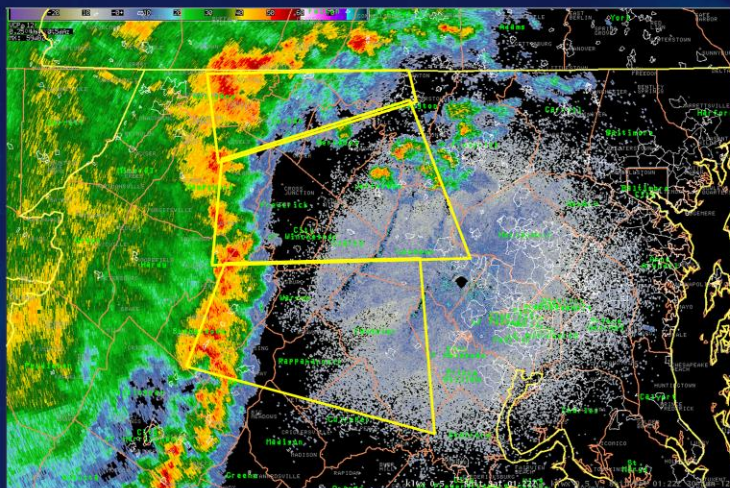


Here’s an example of a typical Severe Thunderstorm Warning issued along a squall line. The strateg



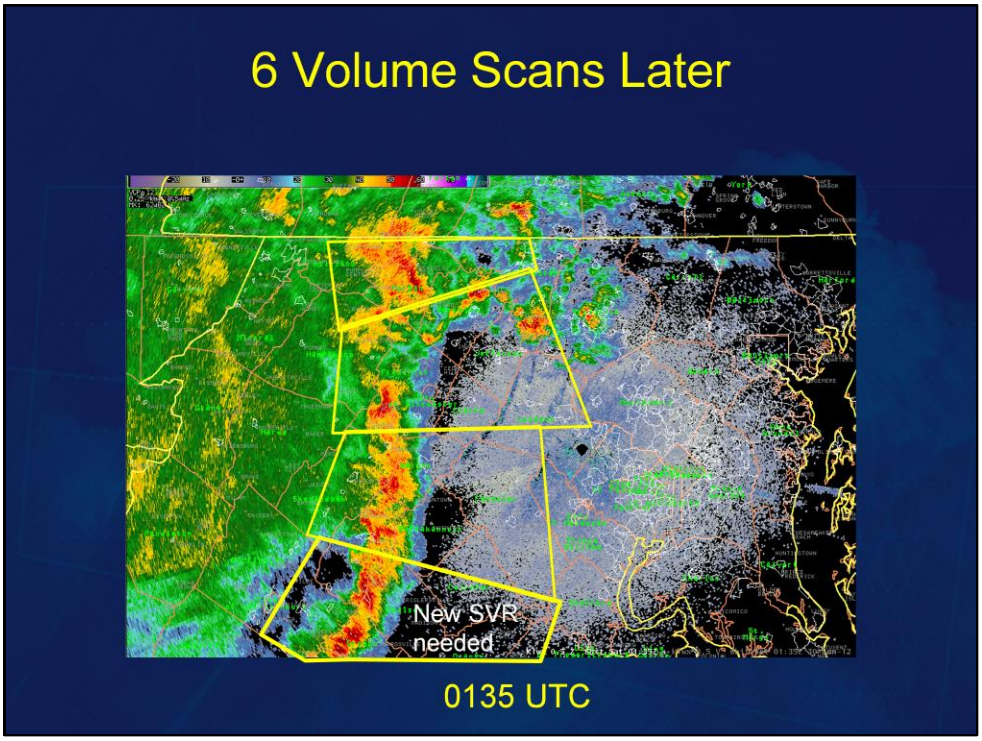
Here's a different warning polygon strategy which cuts down on overlap and obtains maximum lead time for locations on the entrance side of the polygon. These are big polygons so you'll have to watch for text overload. We start the warnings at 0109z, with the assumption that there is an existing warning out for threats to the west of the three new polygons.

3 Volume Scans Later

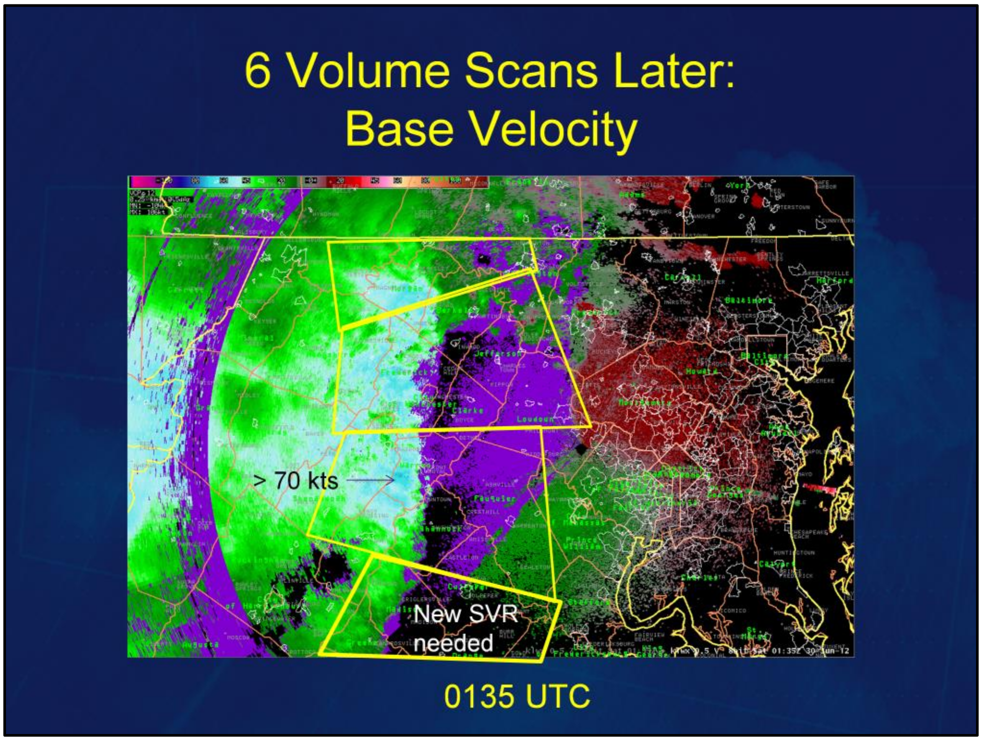


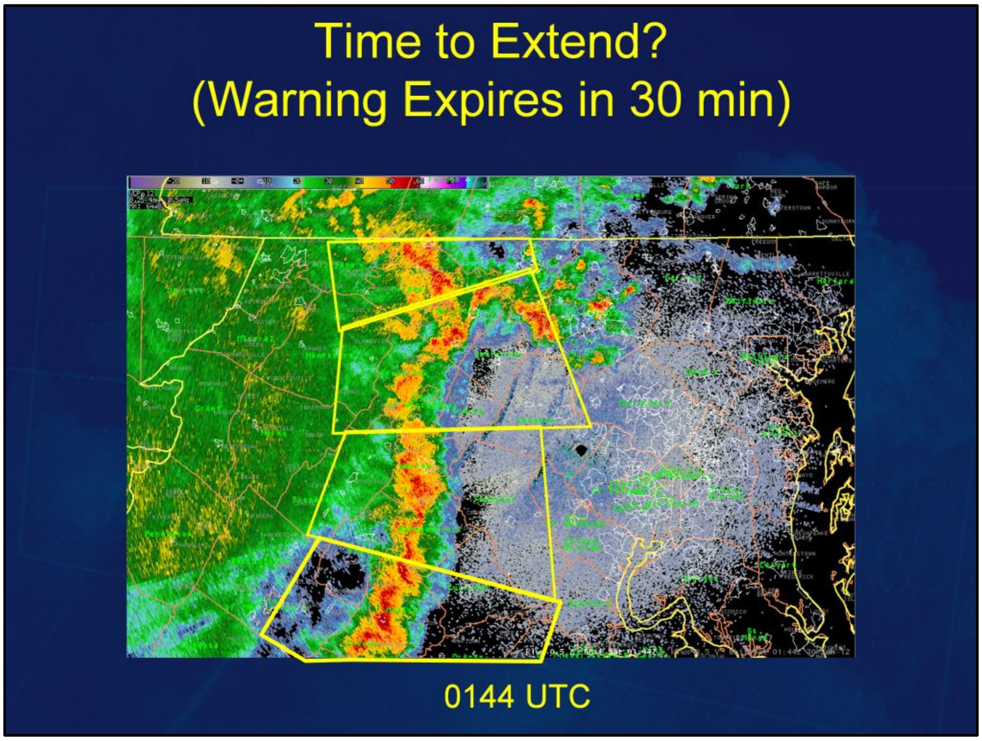
0109 z

Now , 3 volume scans later.

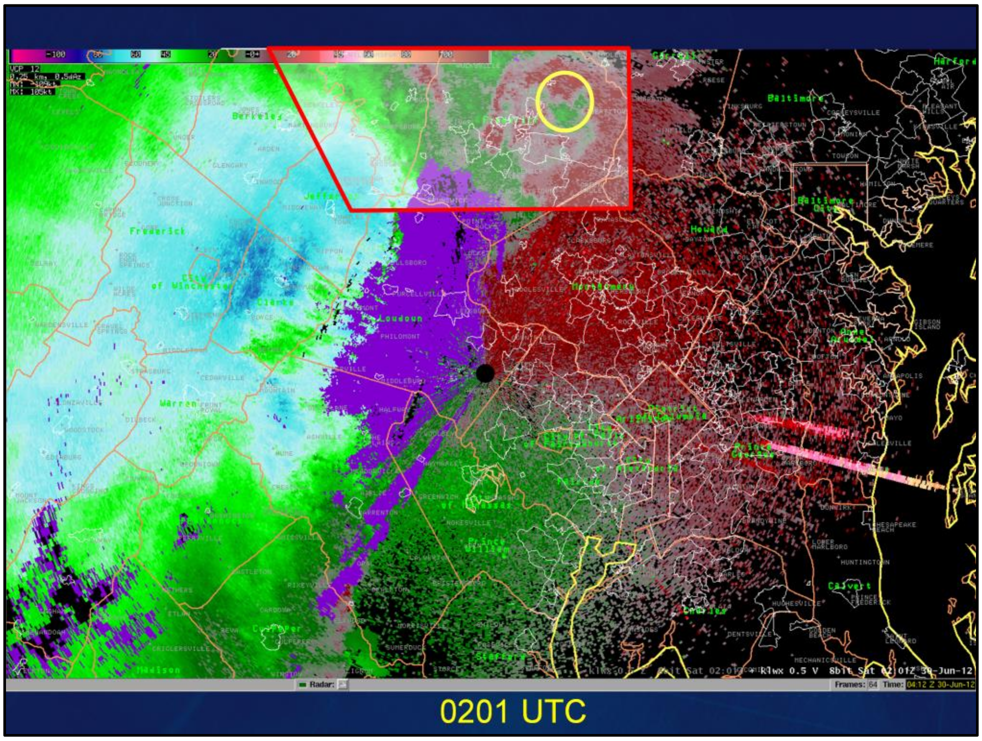


Now, the storms and proposed polygons issued 6 volume scans later.

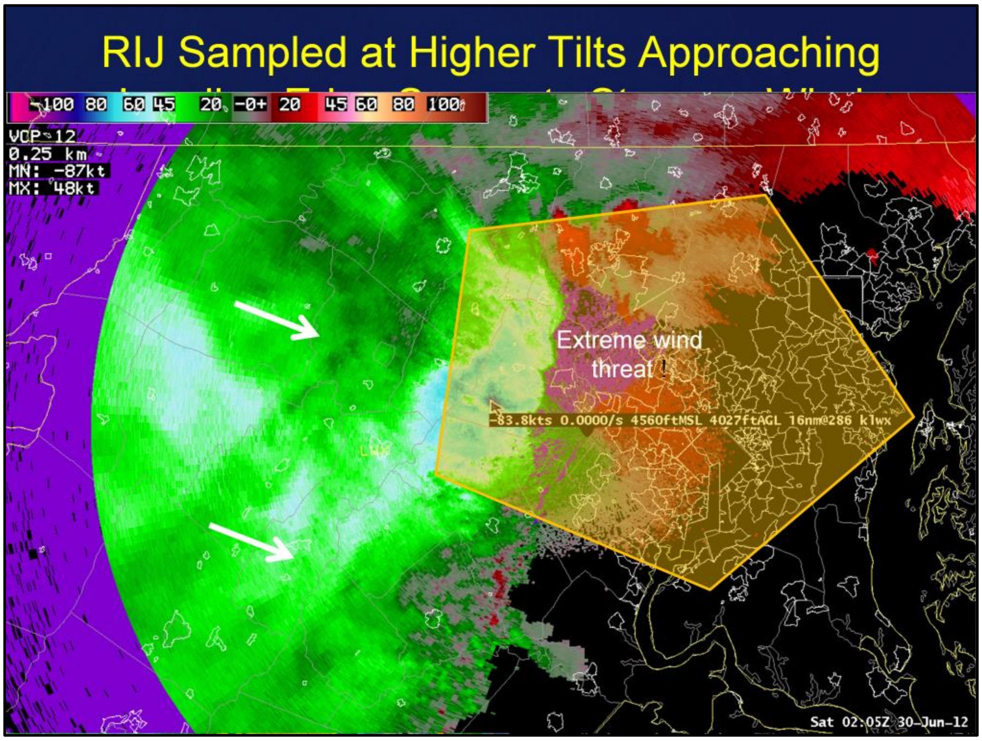

6 Volume Scans Later:
Base Velocity
> 70 kts
New SVR
needed
0135 UTC



Now, the warning still has 30 minutes remaining and plenty of downstream lead time. Compare this situation with what you would have had with a 3 to 1 length to width ratio warning we showed earlier. The next slide shows how I'd update with downstream warnings.



I've re-centered the display at the RDA, zoomed in to view the most intense part of the line, and overlaid the approximate locations of the warnings of interest which expire at 0215z. At this point, you can consolidate some warning threats into the three white polygons shown. These three new warnings provide most of the Washington D.C. metro area with adequate lead times for the impending severe wind threat. Again, you can continue the smaller length to width ratio for polygon size. Note, the warning at the northern-most part of the screen shot is oriented with a smaller length as there is some slower movement near the bookend part of the line. Also, given the velocity data, this might be a possible location for mesovortex development. Hence. This polygon might go red.



Now, we are examining a 2.4 reflectivity tilt at 0205 UTC which is well past the time for an update to the previously shown initial warnings. But the main point here is to illustrate the structure of the QLCS has changed with the intensification of the cold pool and resulting push of the RIJ toward the leading updrafts such that individual updrafts have consolidated and we are seeing more slab-like lifting with the line as well as development of weak echo channels behind the leading edge. As we zoom into a 0.25 km base velocity product, we can see the leading edge of the RIJ just west of the radar, which has increased the ground-relative winds to > 83 kts. These measurements verify the change in the QLCS structure and denote an impending increased intensity of the winds. Thus, I would consider using enhanced wording in the warnings to highlight high-impact winds exceeding 80 kts in the DC metro area by 0230-0245 UTC.

Derecho Quiz

Quiz - 14 questions

Last Modified: May 27, 2015 at 01:06 PM

PROPERTIES

On passing, 'Finish' button: Goes to Next Slide

On failing, 'Finish' button: Goes to Next Slide

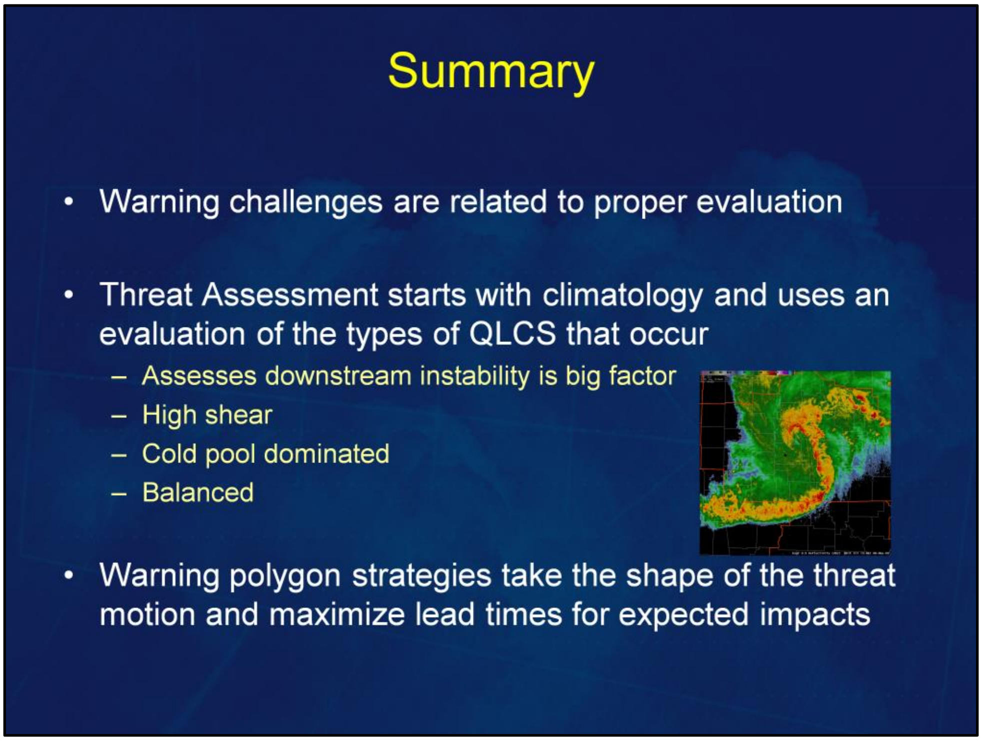
Allow user to leave quiz: At any time

User may view slides after quiz: At any time

Show in menu as: Single item

Edit in Quizmaker

Edit Properties



Warning challenges are related to proper evaluation.

Threat Assessment starts with climatology and uses an evaluation of the types of QLCS that occur. Downstream instability is a big factor in intensity and maintenance of the system.

Some QLCS will fit models that are:

High shear dominated or

Cold pool dominated, or

Balanced (in these cases, the RIJ helps to restore the balance). Storm interrogation strategies should be based on the type of balance.

Warning polygon strategies should take the shape of the threat motion and maximize lead times for expected impacts in the polygons. Some overlap is acceptable given these warning goals.

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